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(54) **ROBOTICALLY-CONTROLLED MOTORIZED SURGICAL INSTRUMENT**

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See application file for complete search history.

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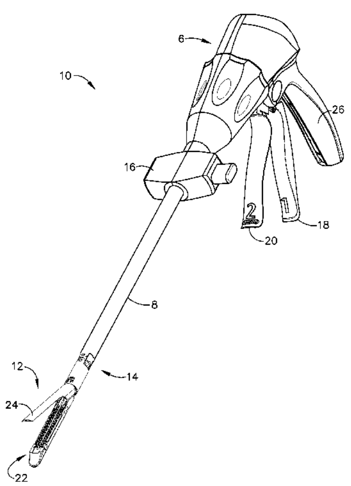
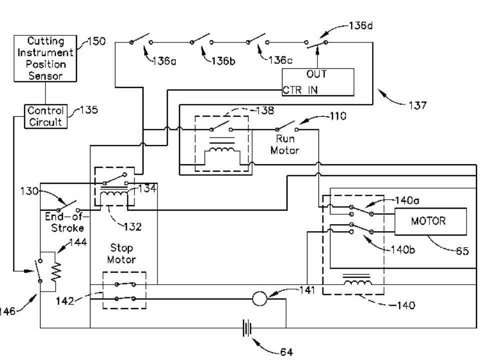
(57) **ABSTRACT**

A surgical cutting and fastening instrument that is motorized and configured for operation in connection with a robotic system. The instrument comprises in one embodiment a charge accumulator device, separate from a battery, that provides additional power to the motor under certain conditions. In addition, the motor may comprise multiple windings.

18 Claims, 109 Drawing Sheets





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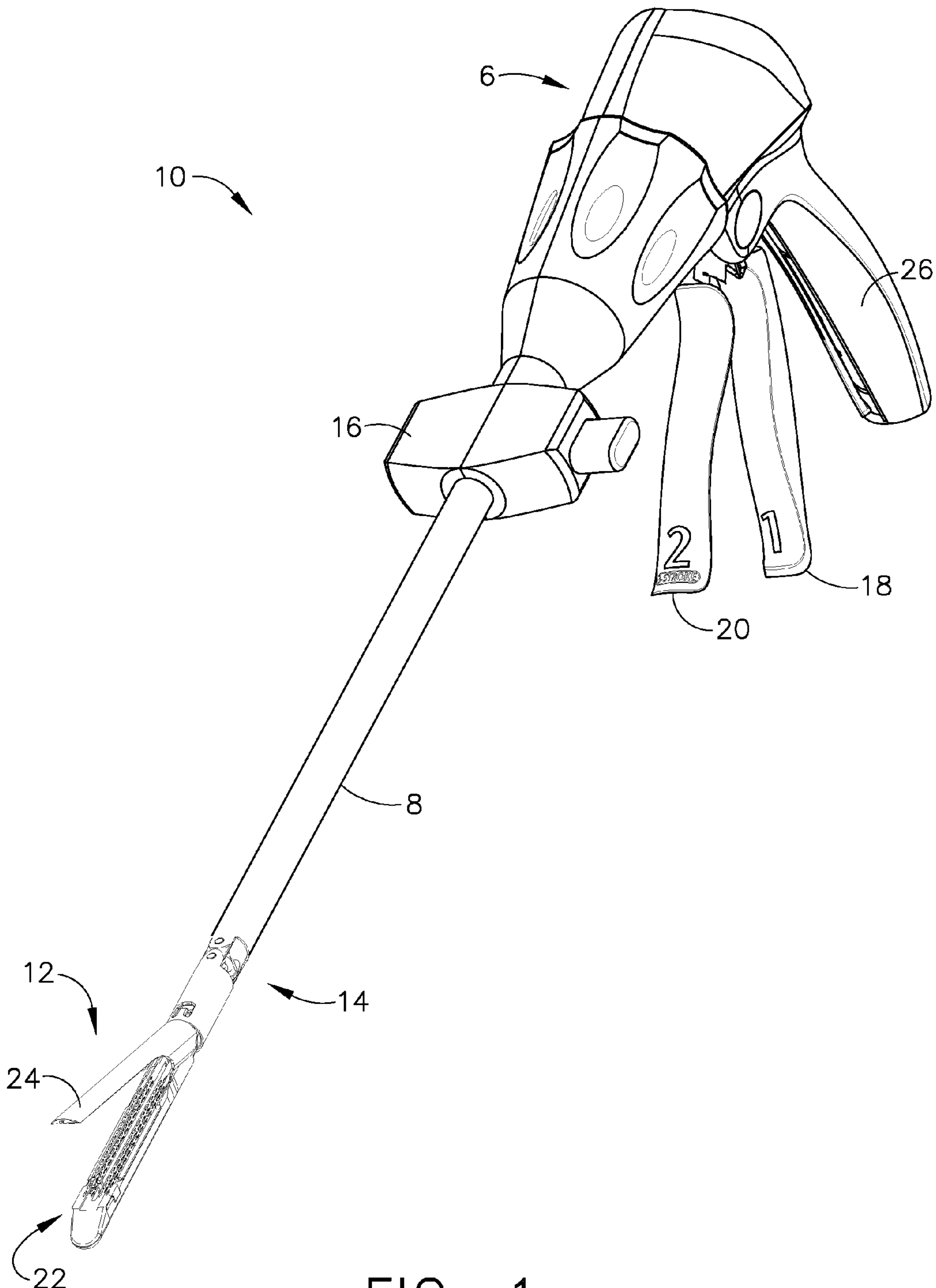

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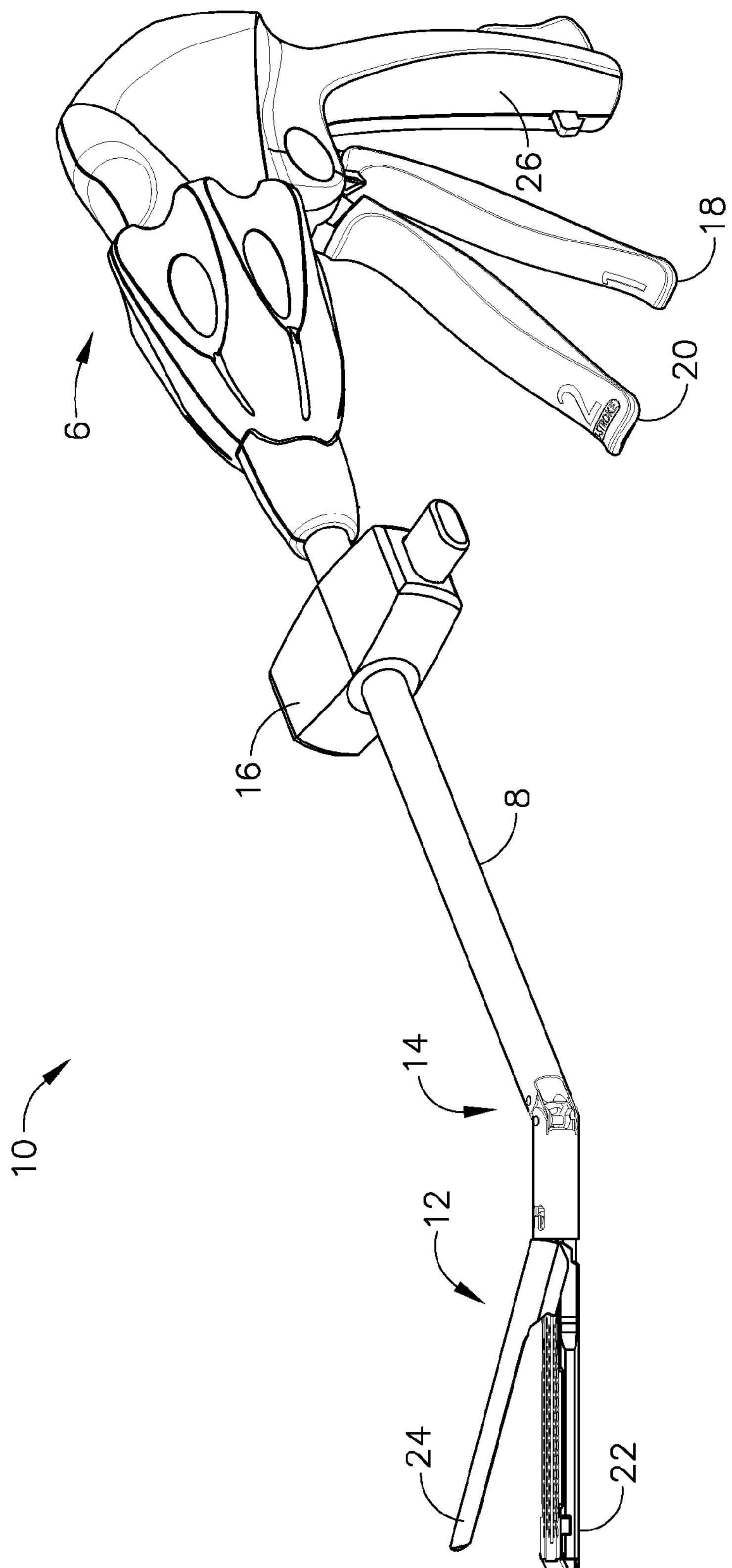

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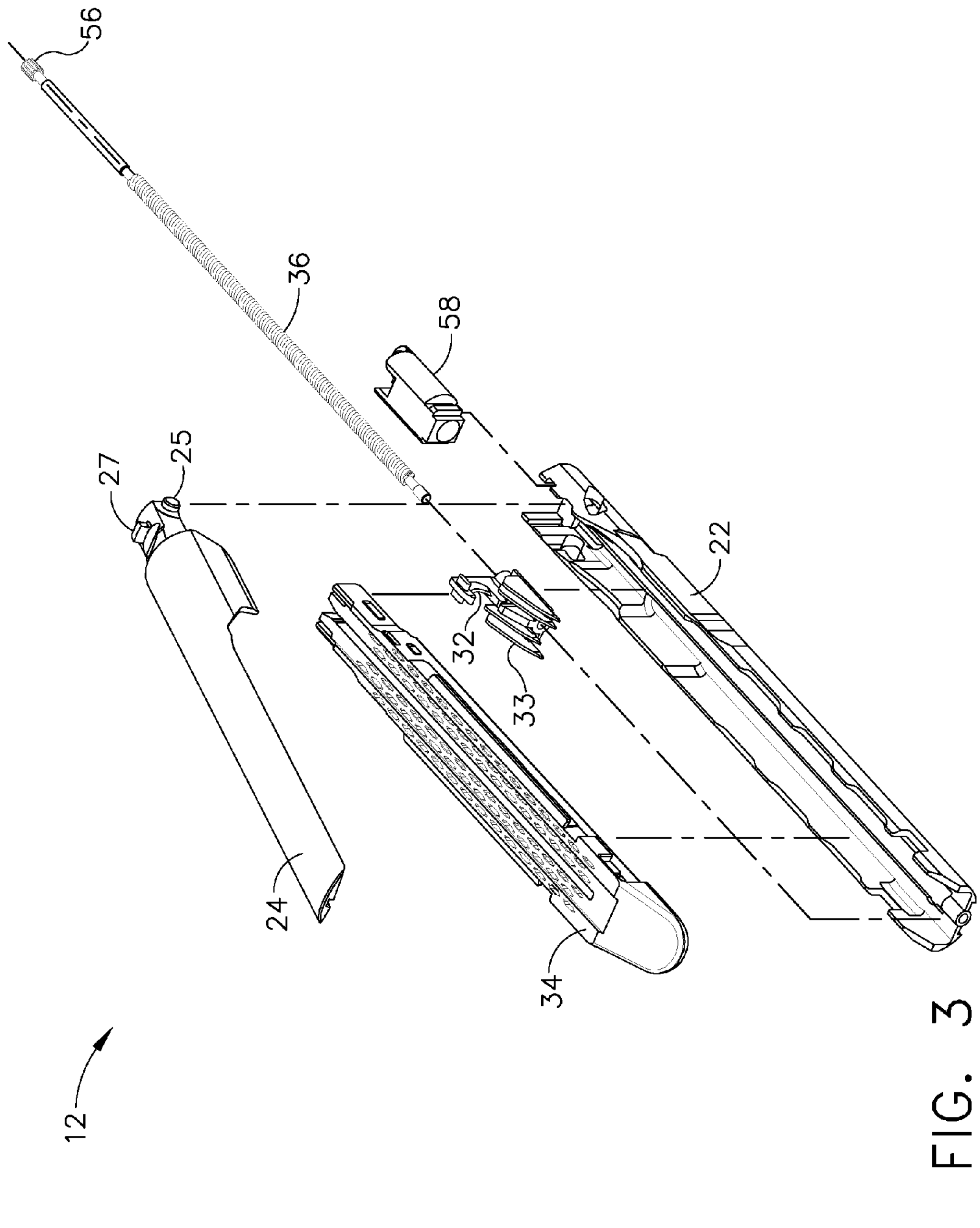
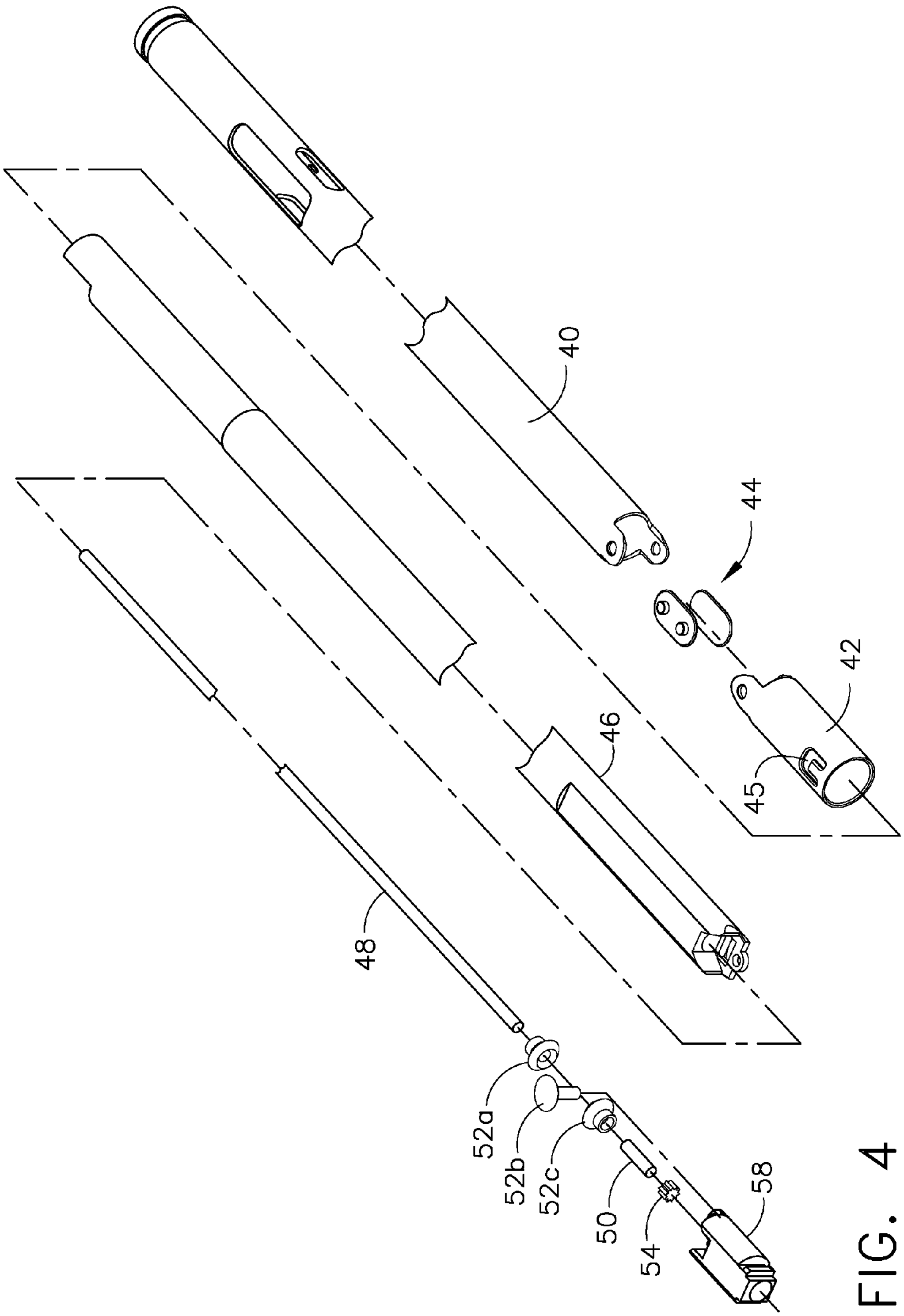


FIG. 3



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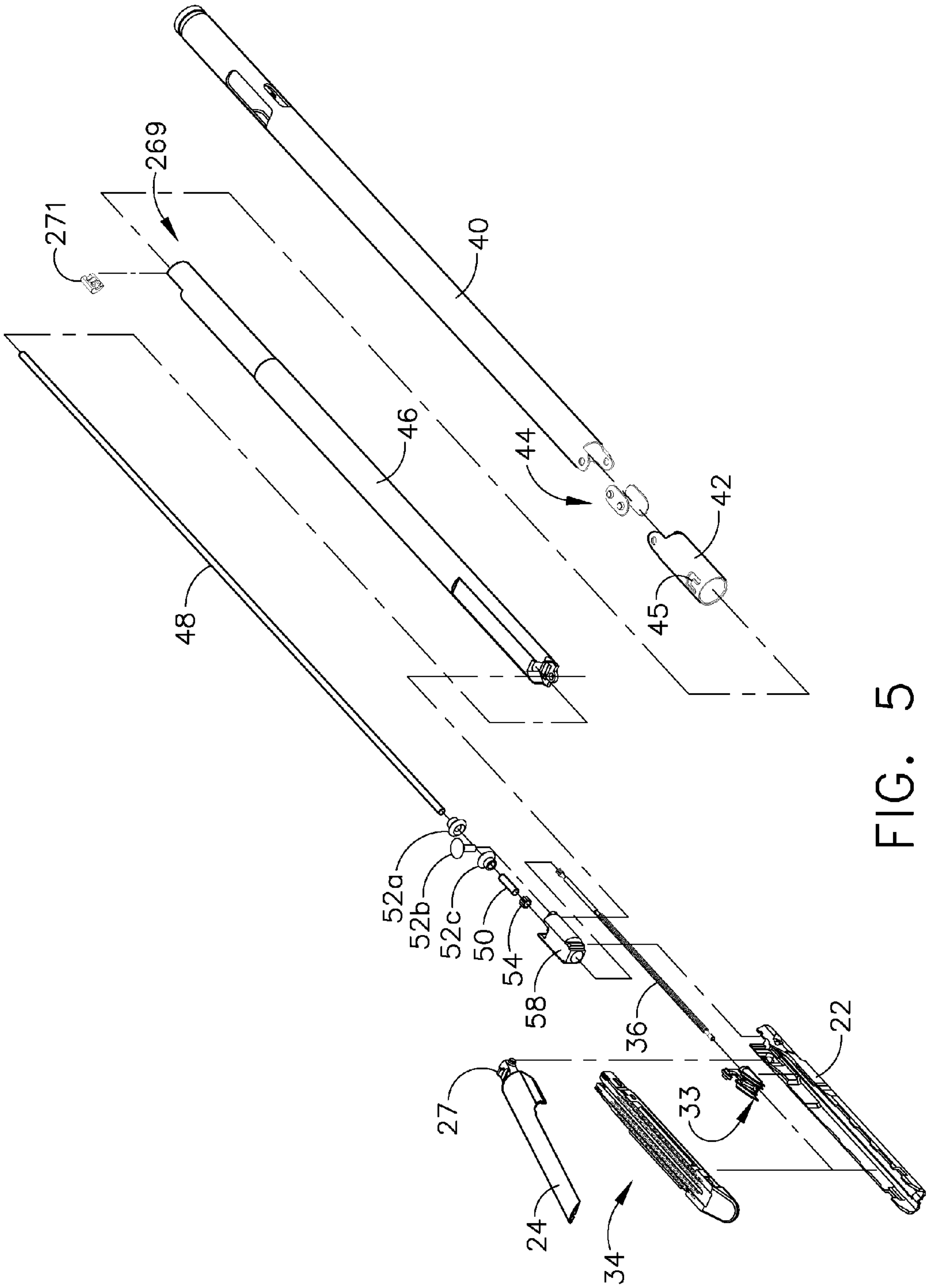
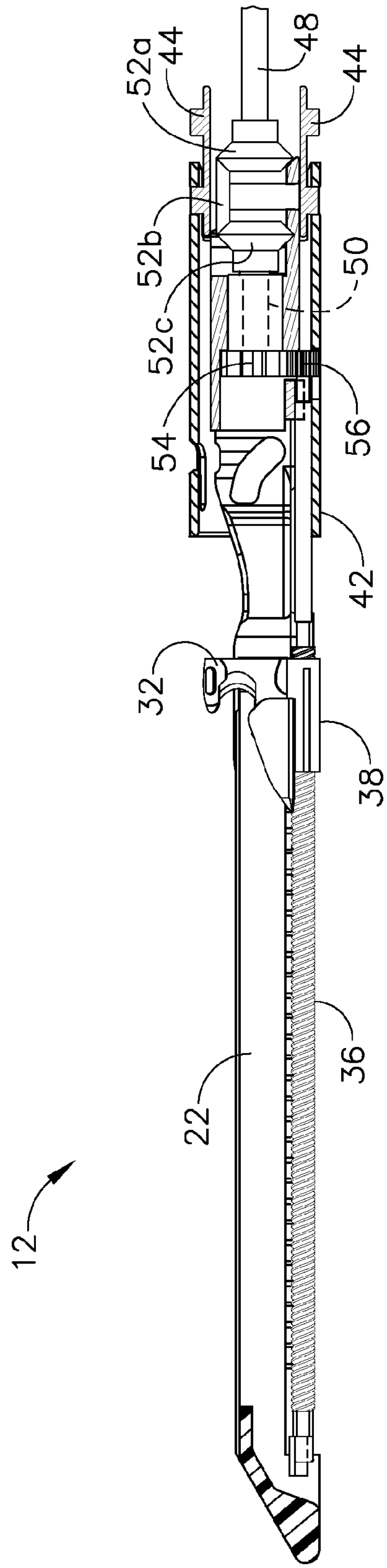


FIG. 5



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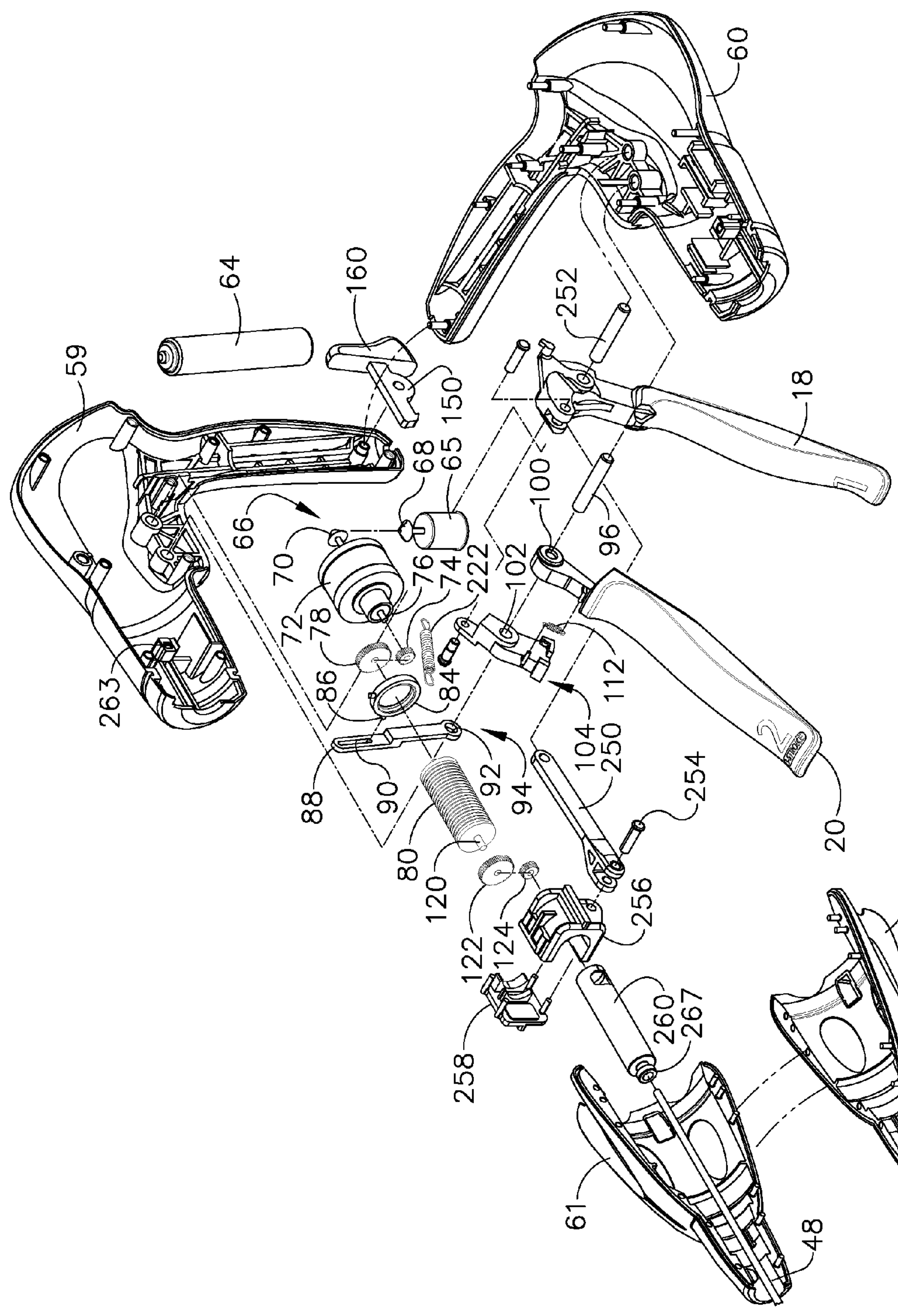
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FIG. 7

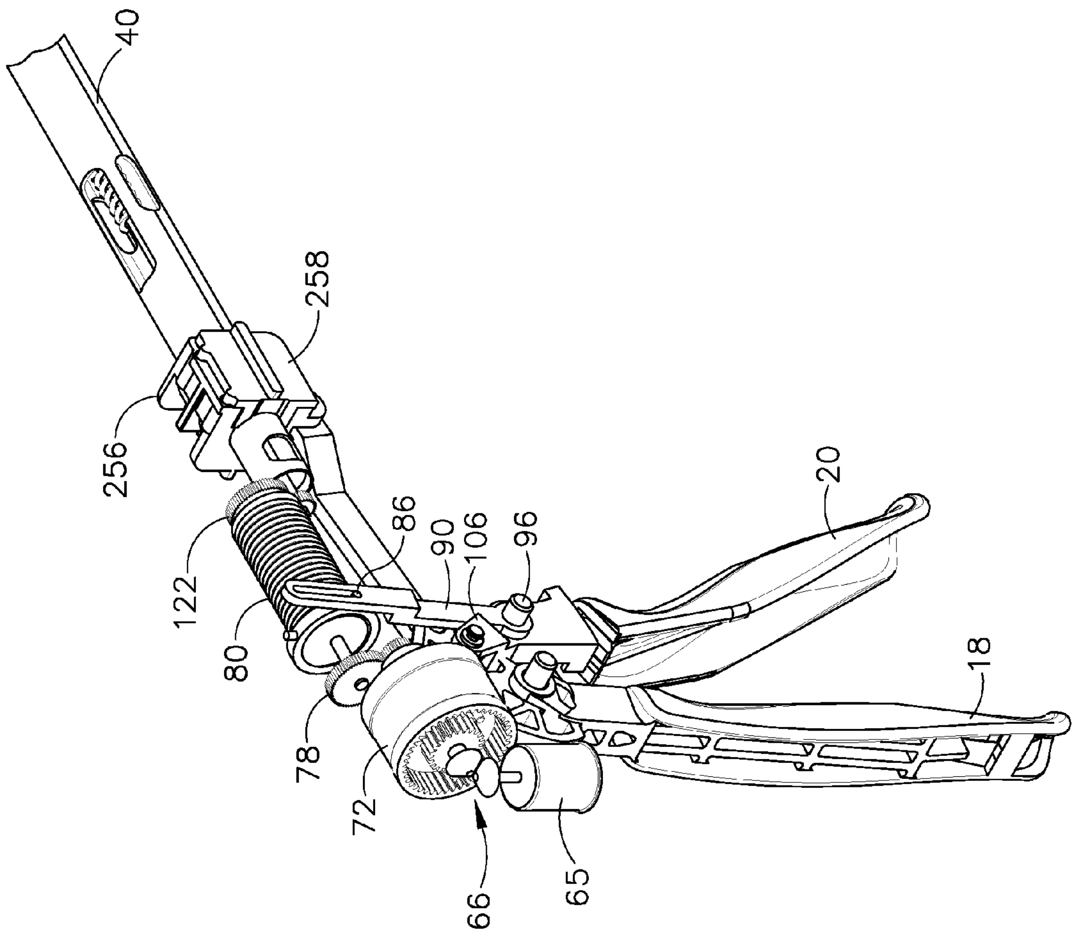


FIG. 8

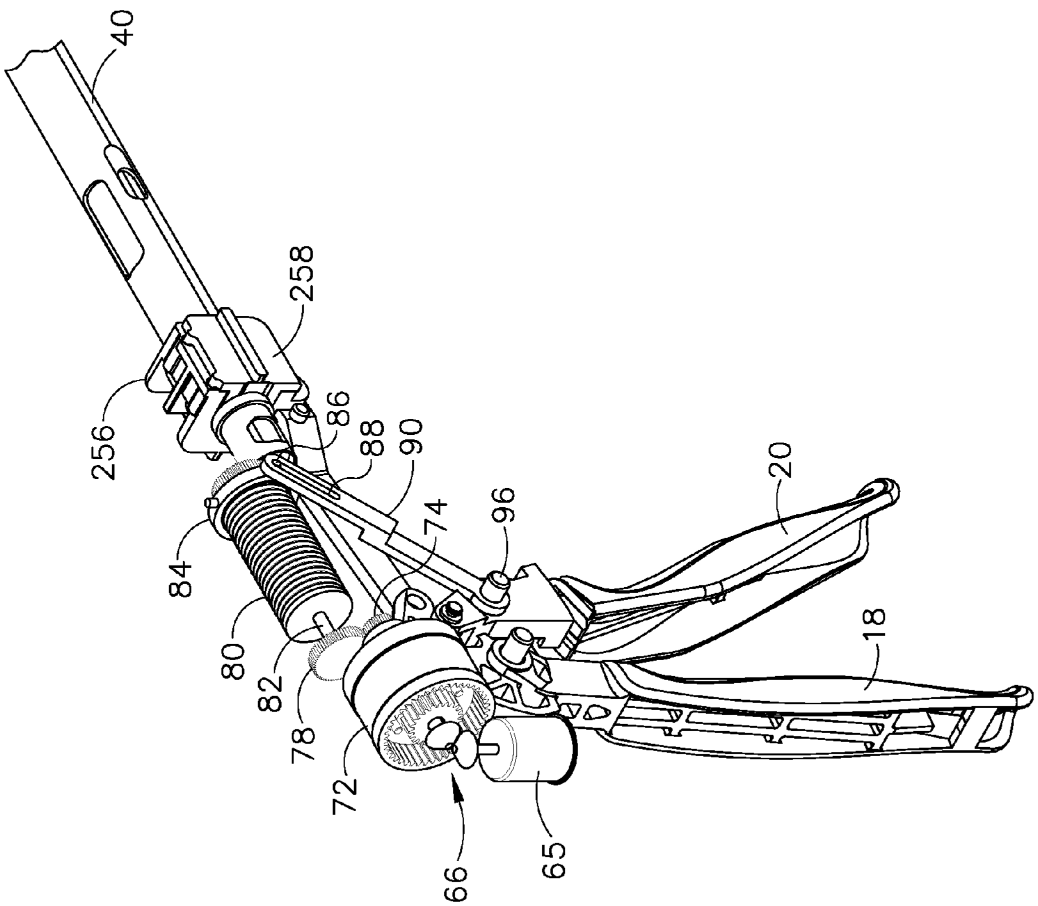


FIG. 9

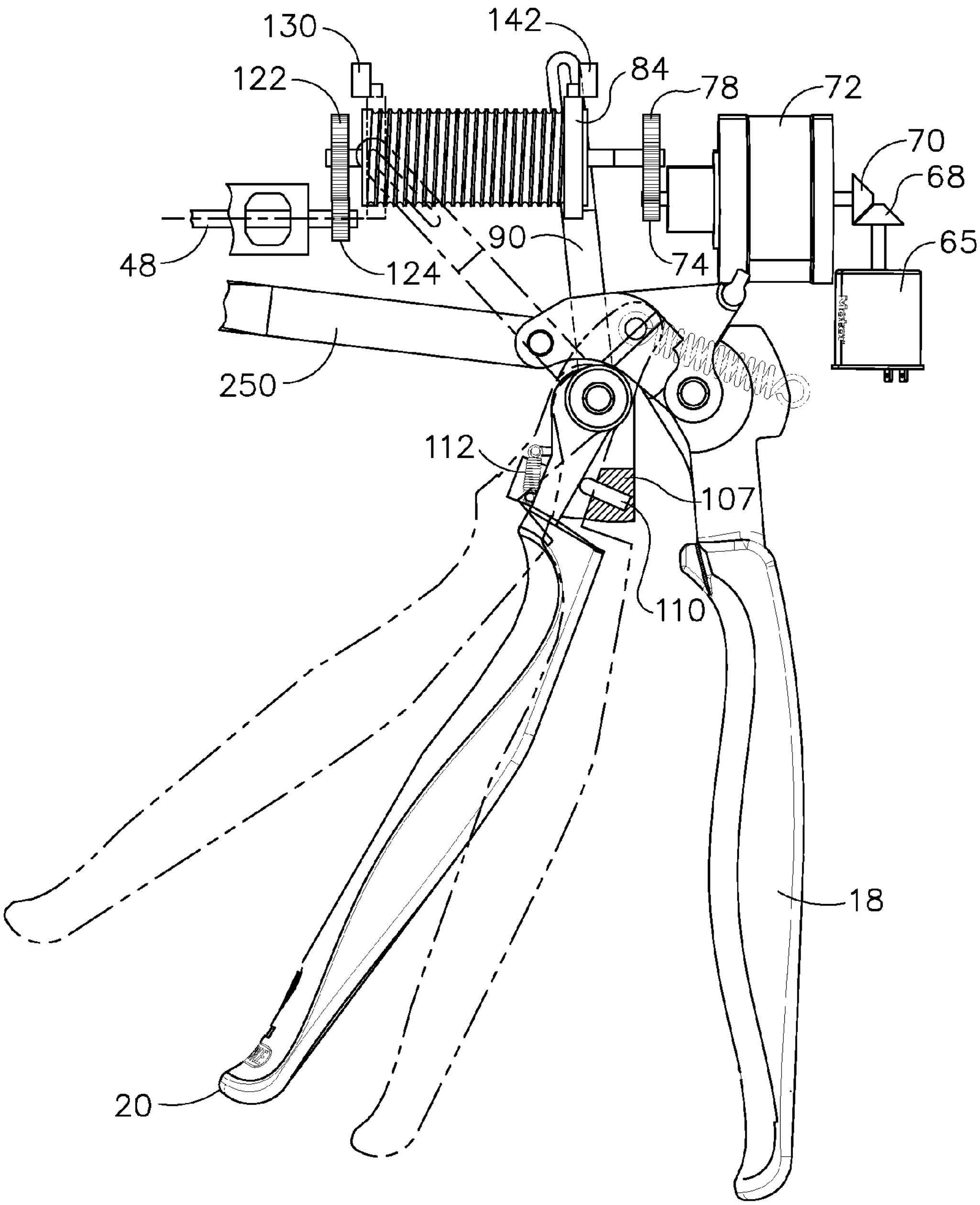


FIG. 10

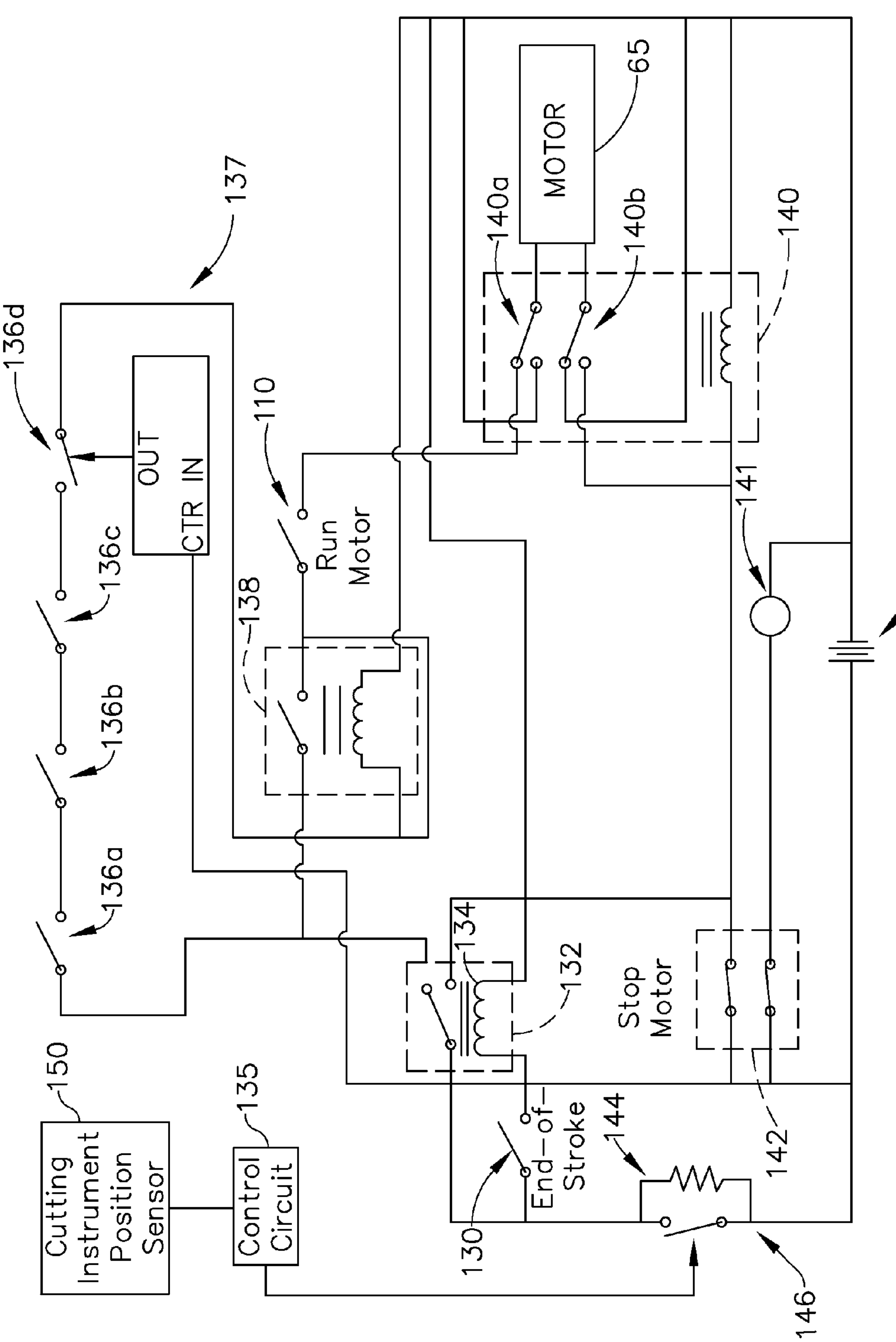

MOTOR
65
140a
140b
140
137
136d
OUT
CTR IN
136c
136b
136a
110
Run Motor
138
141
64
134
132
Stop Motor
142
150
Cutting Instrument Position Sensor
135
Control Circuit
144
End-of-Stroke
130
146

FIG. 11

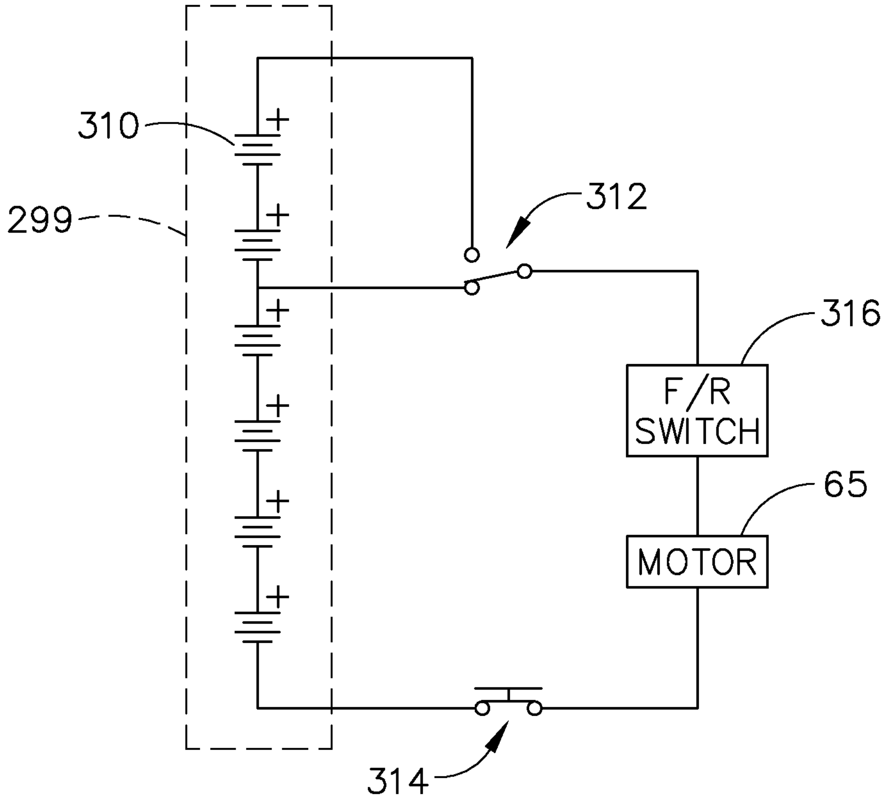

310
299
312
316
F/R SWITCH
65
MOTOR
314

FIG. 12

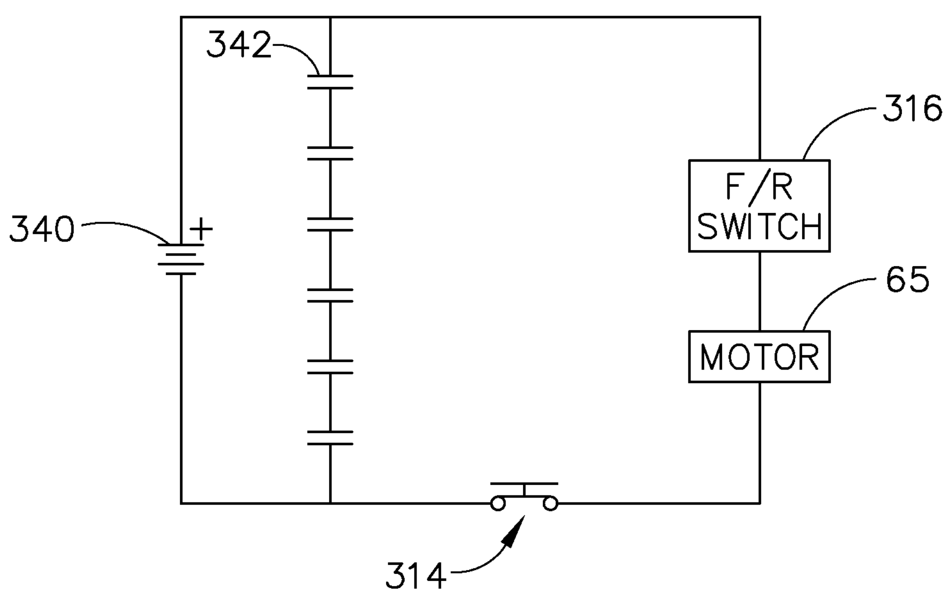

342
340
316
F/R SWITCH
65
MOTOR
314

FIG. 13

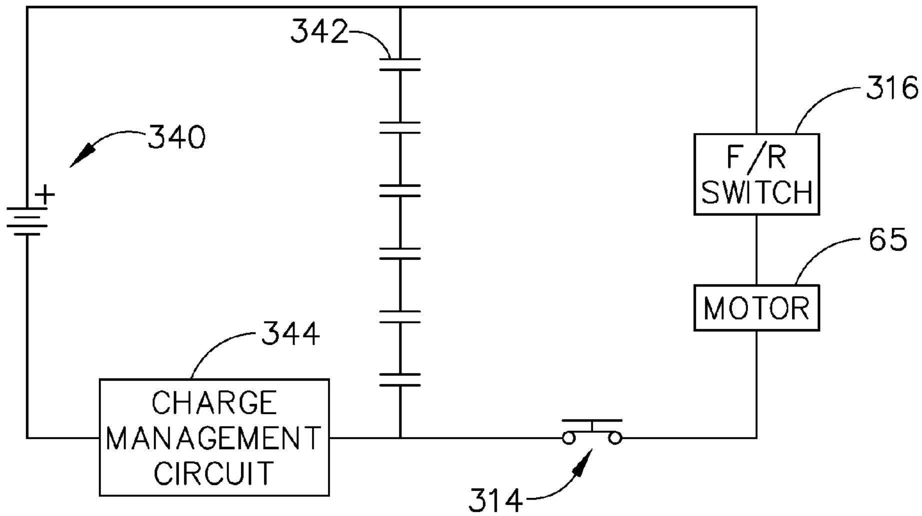

342
316
340
+
F/R
SWITCH
65
MOTOR
344
CHARGE
MANAGEMENT
CIRCUIT
314

FIG. 14

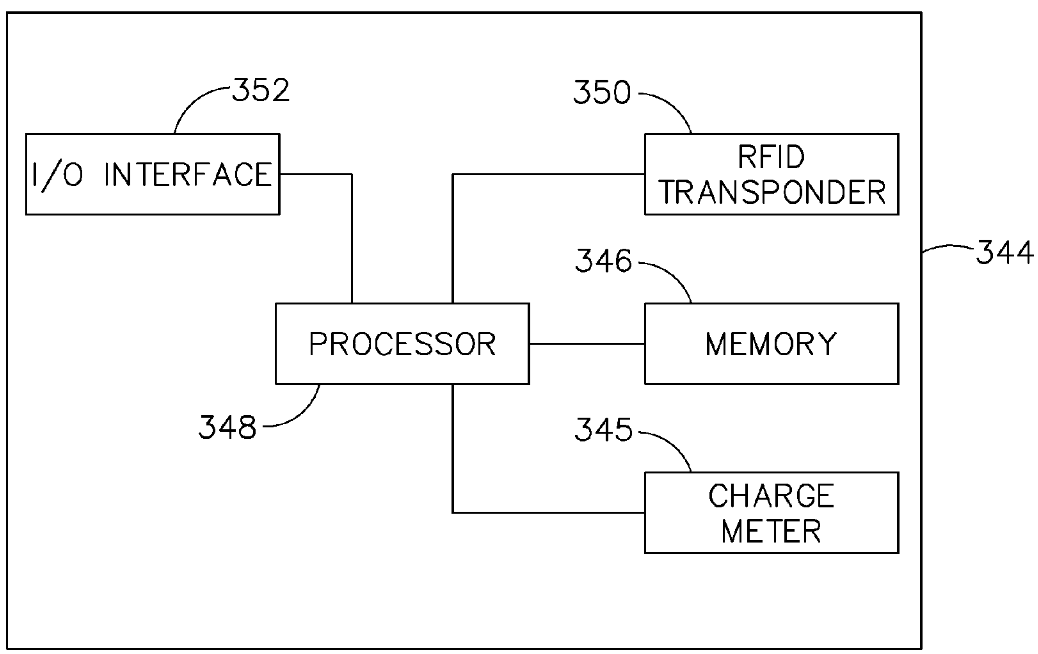

352
350
I/O INTERFACE
RFID
TRANSPONDER
344
346
PROCESSOR
MEMORY
348
345
CHARGE
METER

FIG. 15

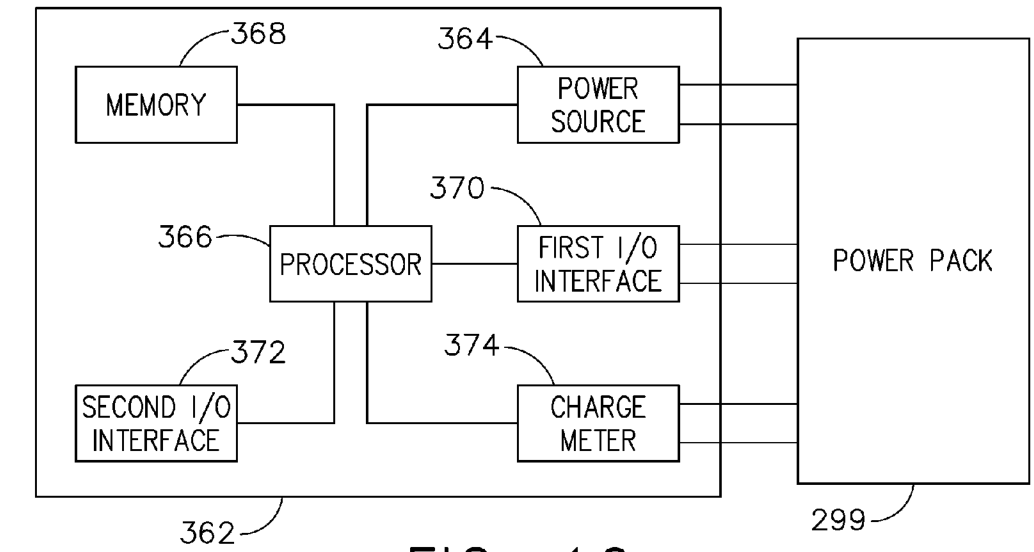

368
MEMORY
364
POWER SOURCE
370
366
PROCESSOR
FIRST I/O INTERFACE
POWER PACK
372
374
SECOND I/O INTERFACE
CHARGE METER
362
299

FIG. 16

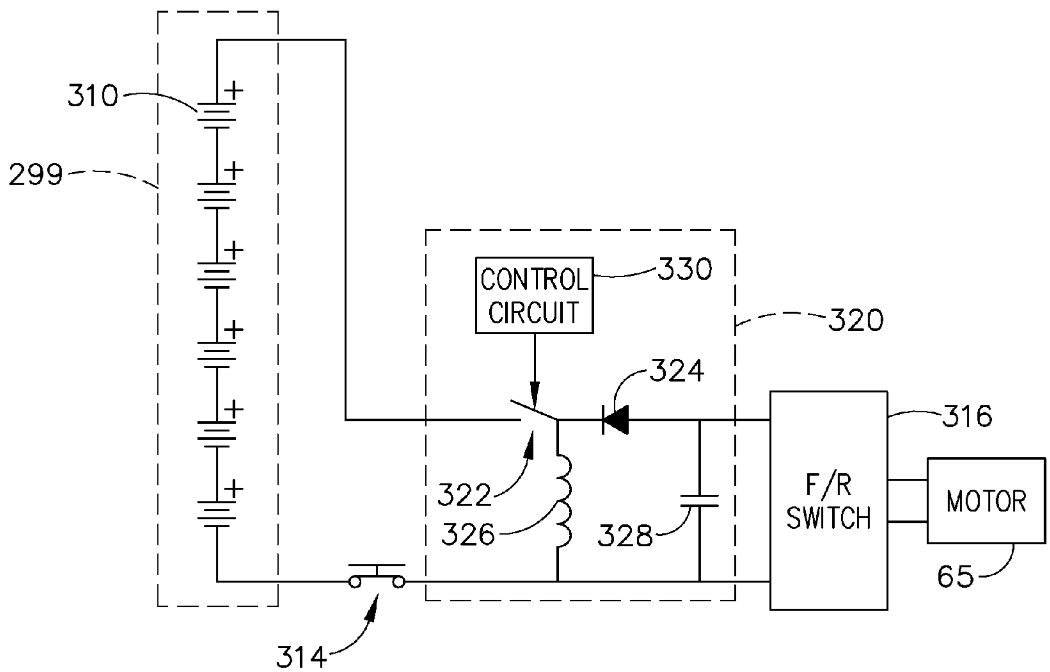

310
299
CONTROL CIRCUIT
330
320
324
316
F/R SWITCH
MOTOR
322
326
328
65
314

FIG. 17

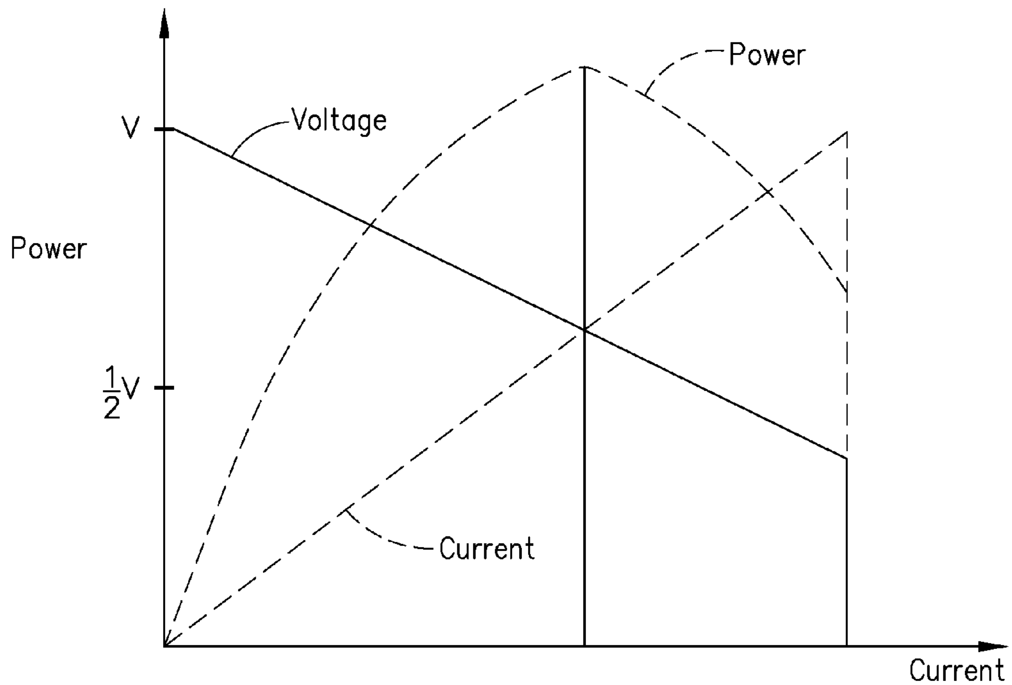


FIG. 18

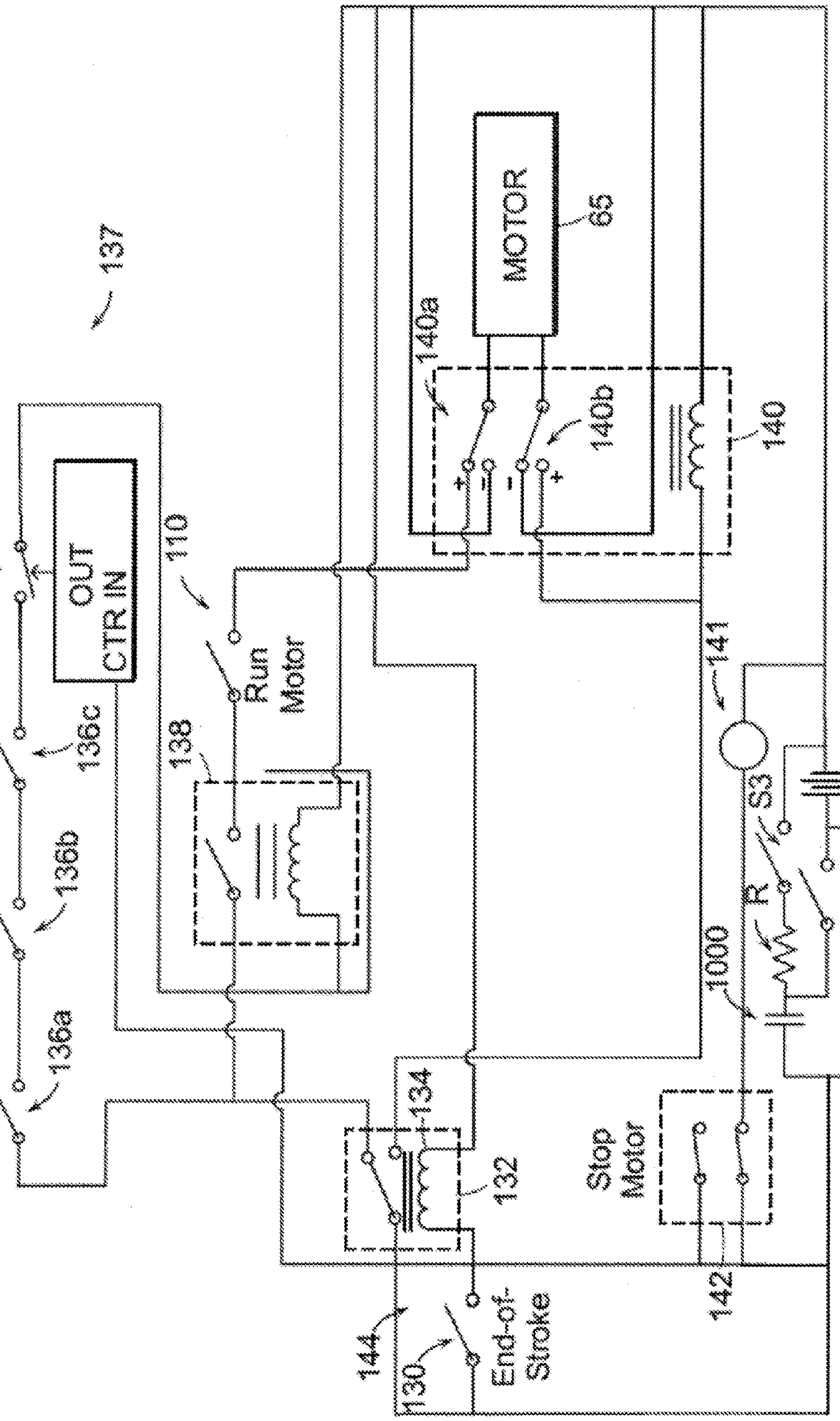

137
136d
OUT
CTR IN
110
Run
Motor
136c
138
136b
136a
134
132
Stop
Motor
144
130
End-of-
Stroke
142
MOTOR
65
140a
140b
140
141
64
S3
S2
S1
R
1000

FIG. 19

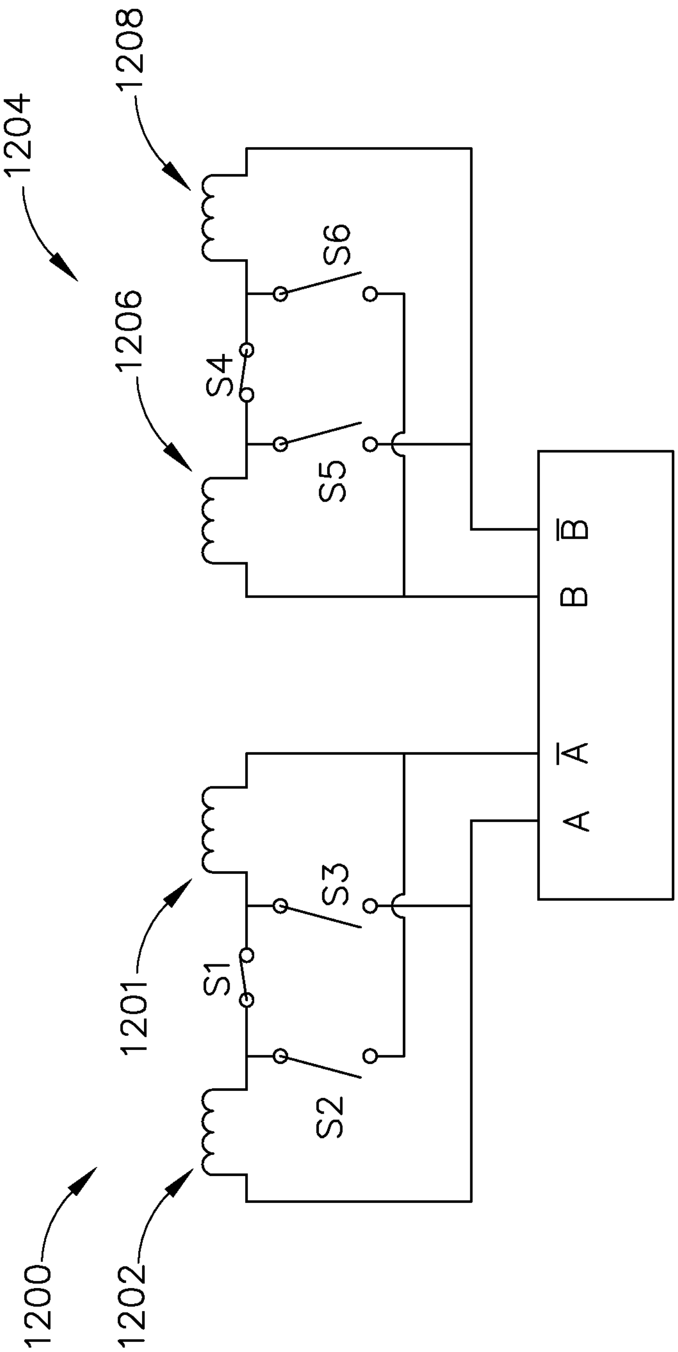


FIG. 20

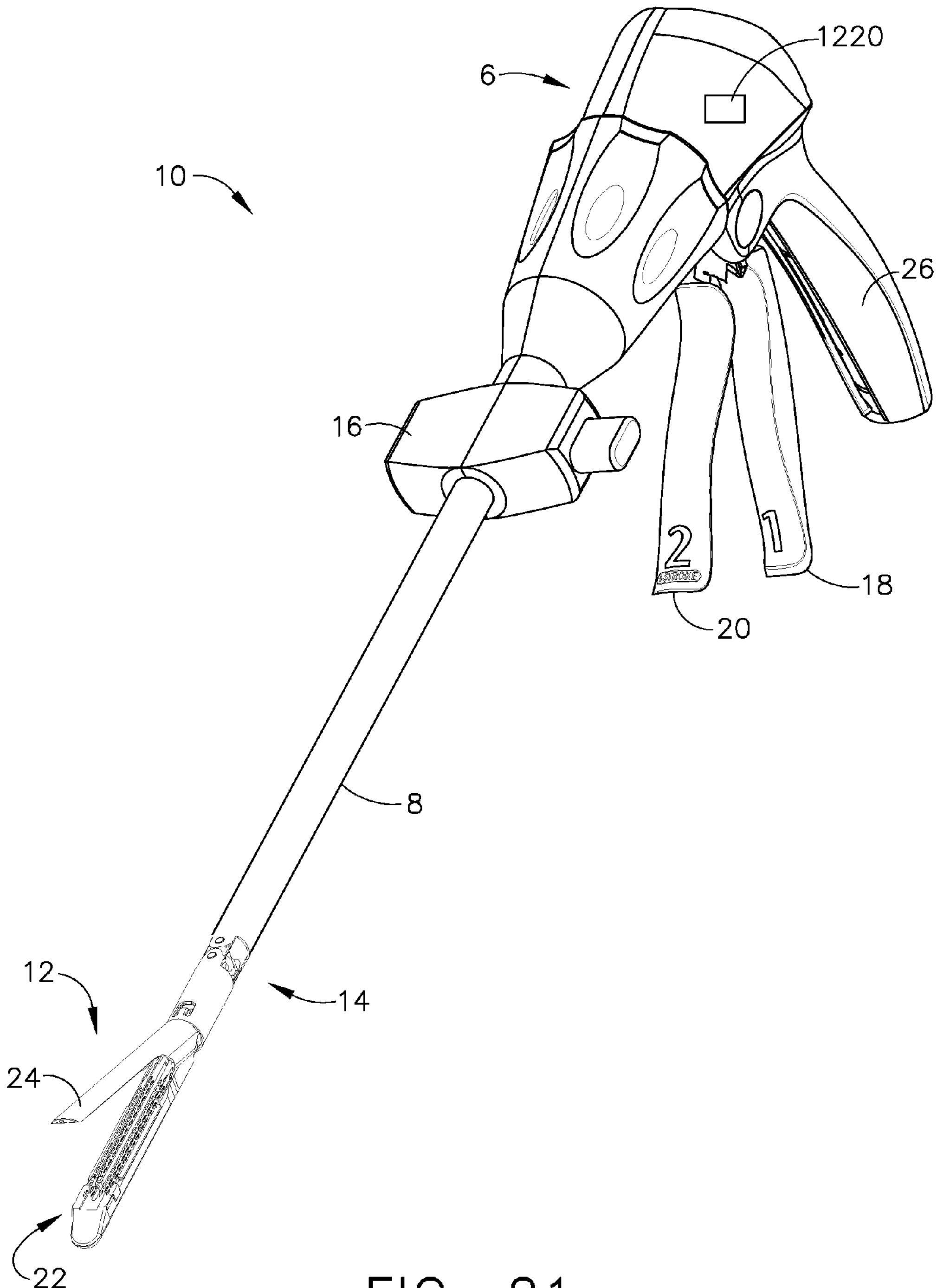


FIG. 21

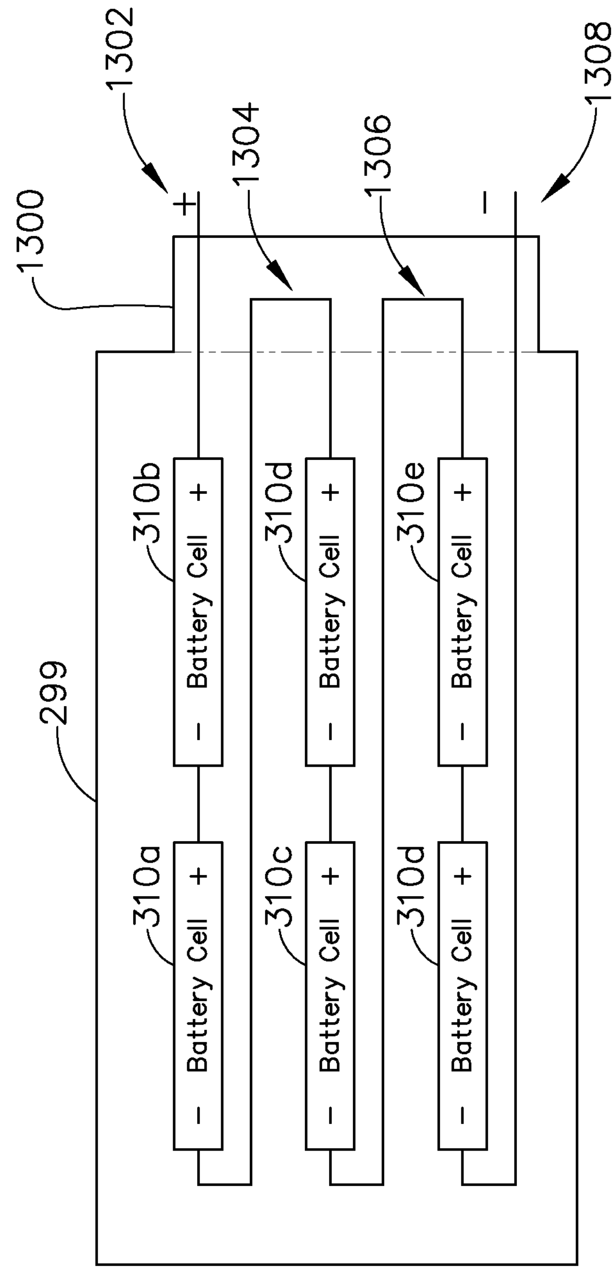

1300
1302
1304
1306
1308
299
310a
310b
310c
310d
310d
310e
Battery Cell
Battery Cell
Battery Cell
Battery Cell
Battery Cell
Battery Cell

FIG. 22

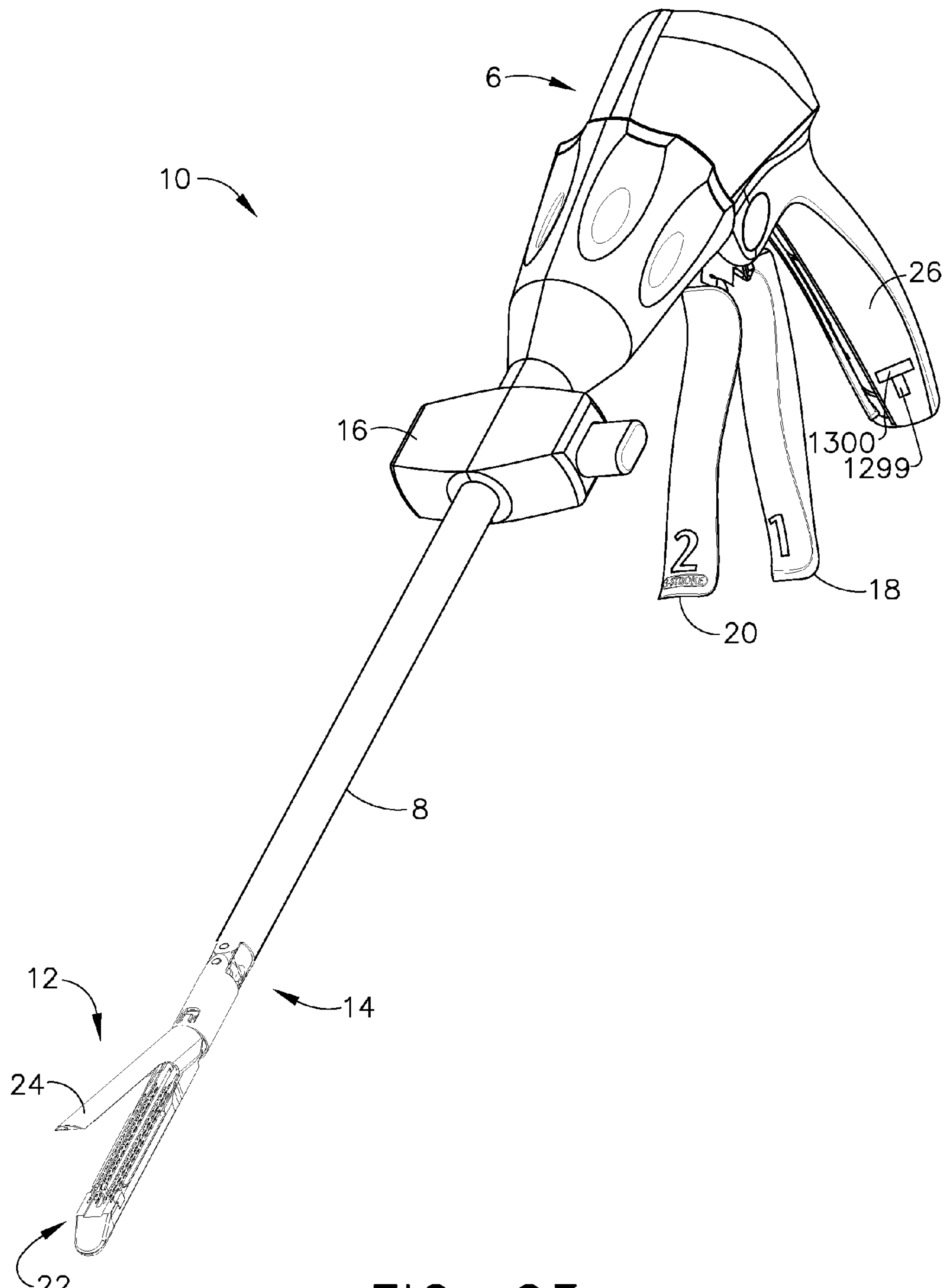


FIG. 23

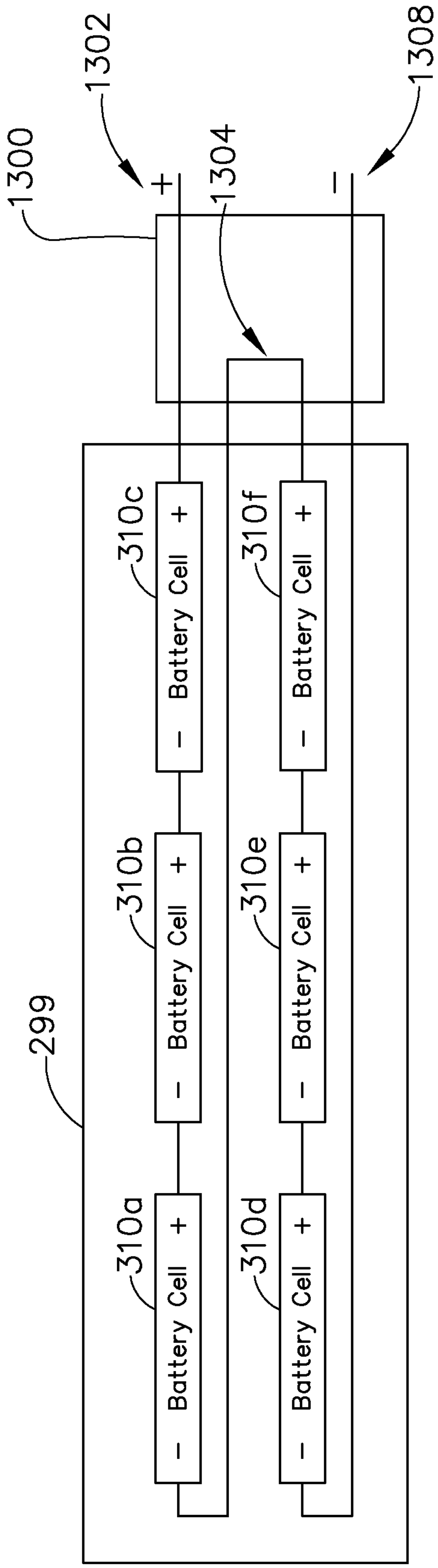

1302
1308
1300
1304
+
−
299
310a
310b
310c
310d
310e
310f
Battery Cell

FIG. 24

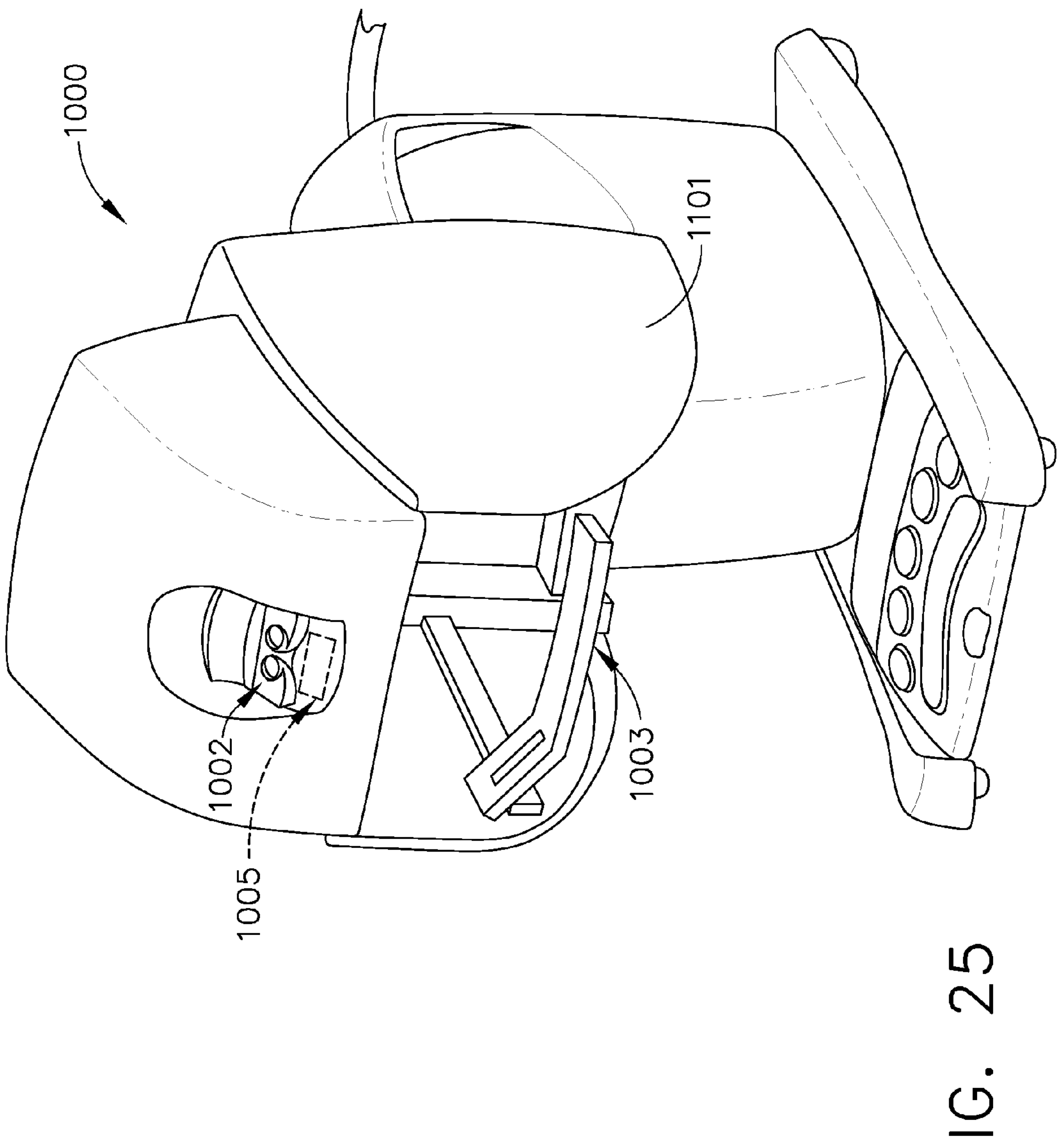


FIG. 25

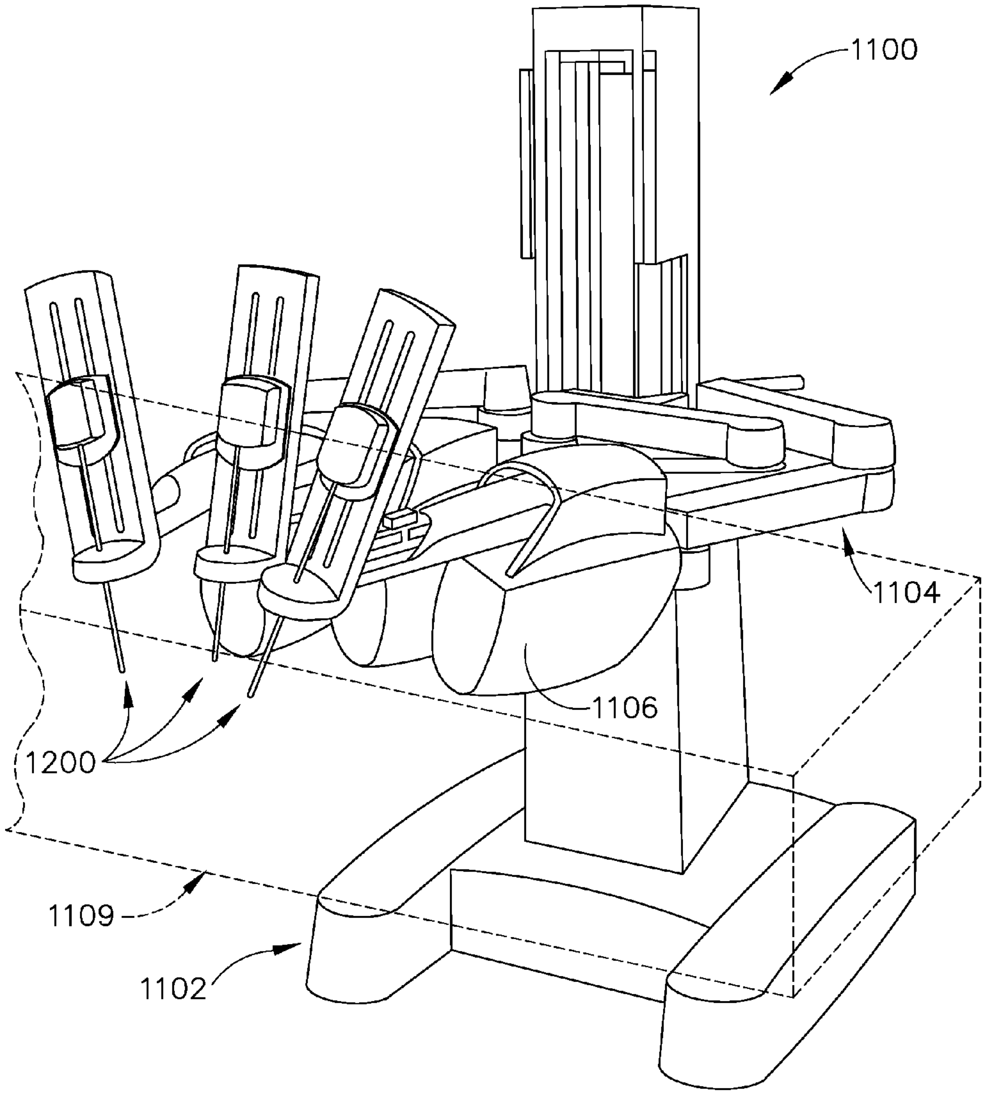


FIG. 26

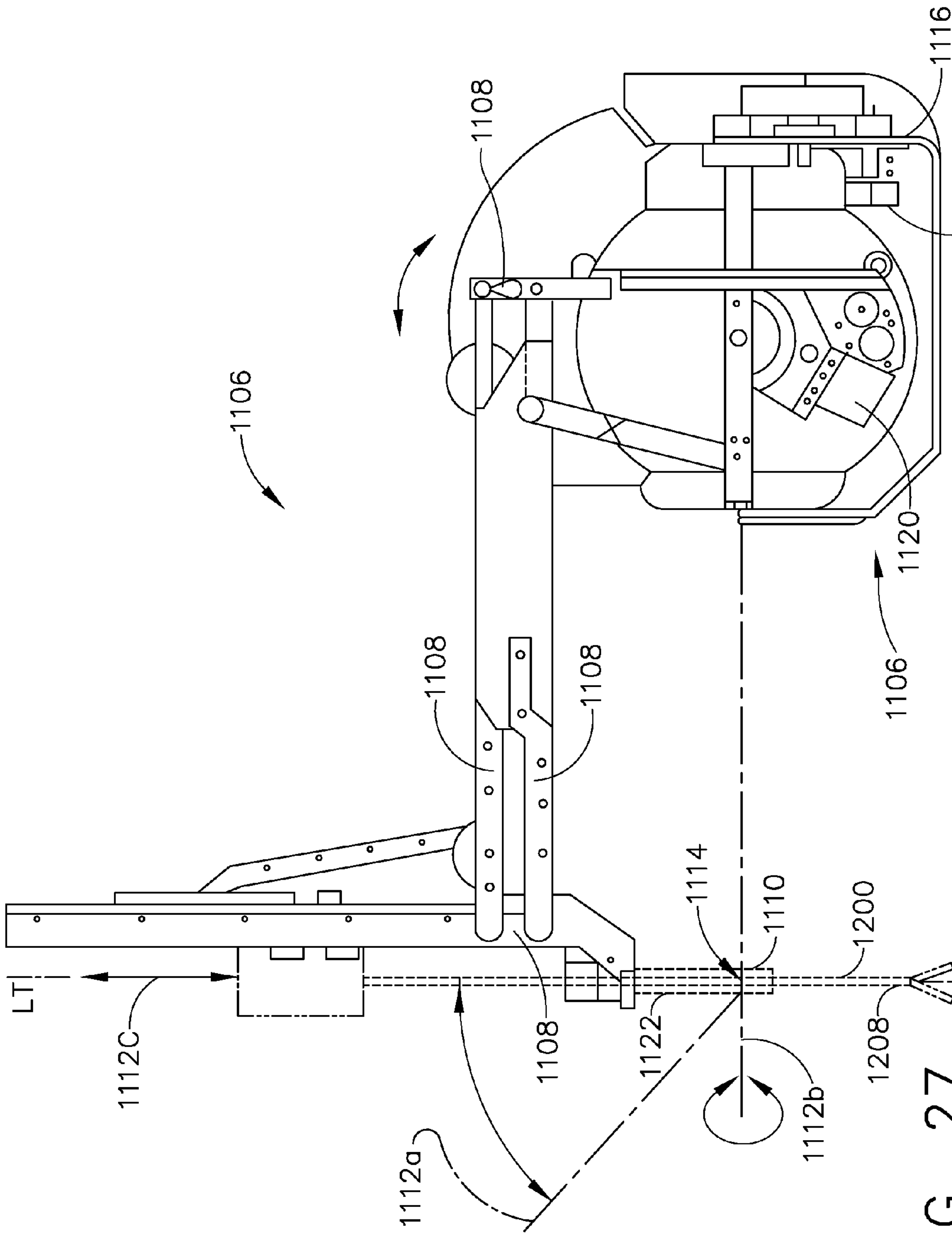

1106
1108
1116
1120
1106
1120
1108
1108
1114
1110
1200
LT
1112C
1108
1122
1208
LT
1112b
1112a

FIG. 27

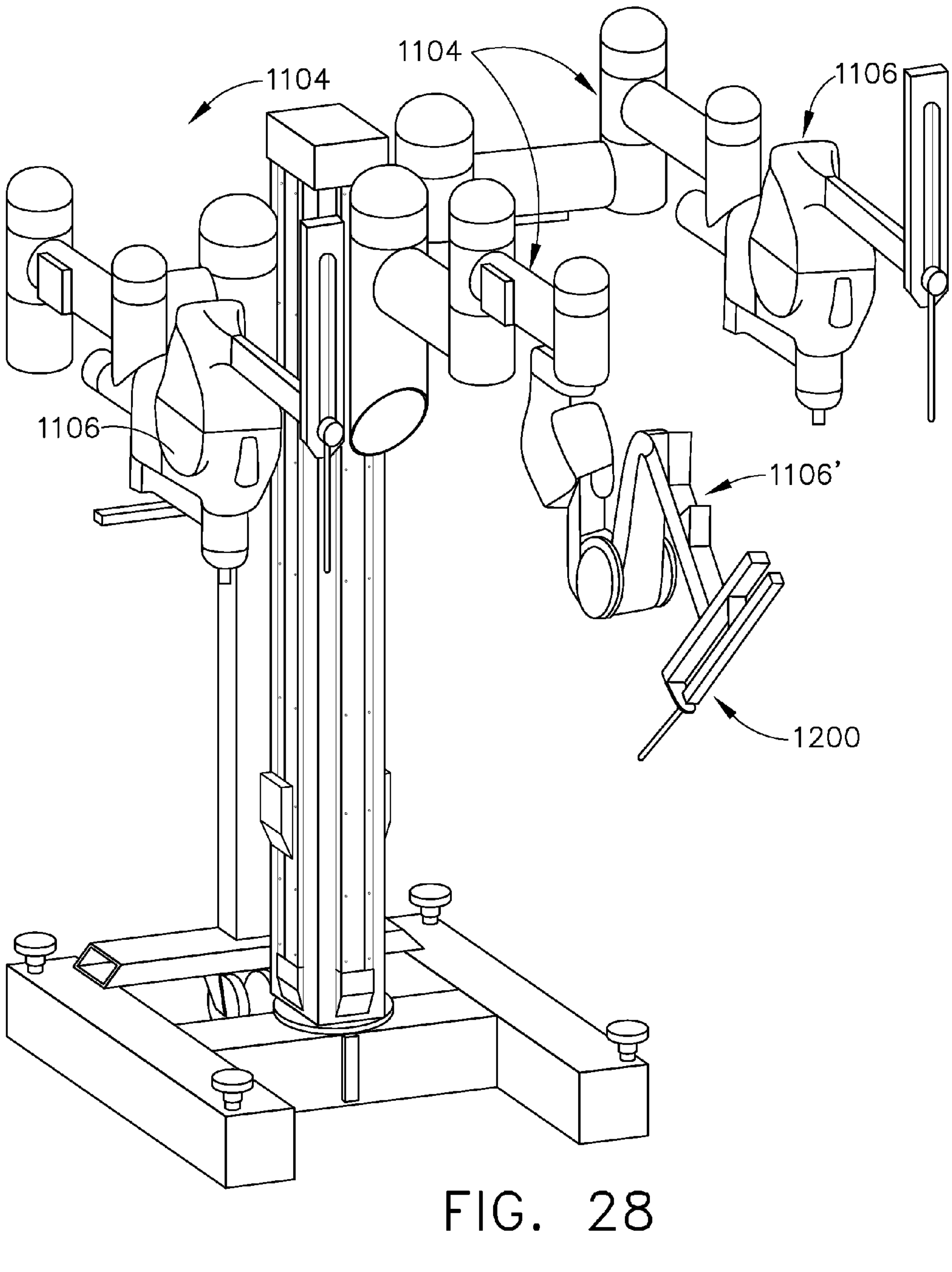


FIG. 28

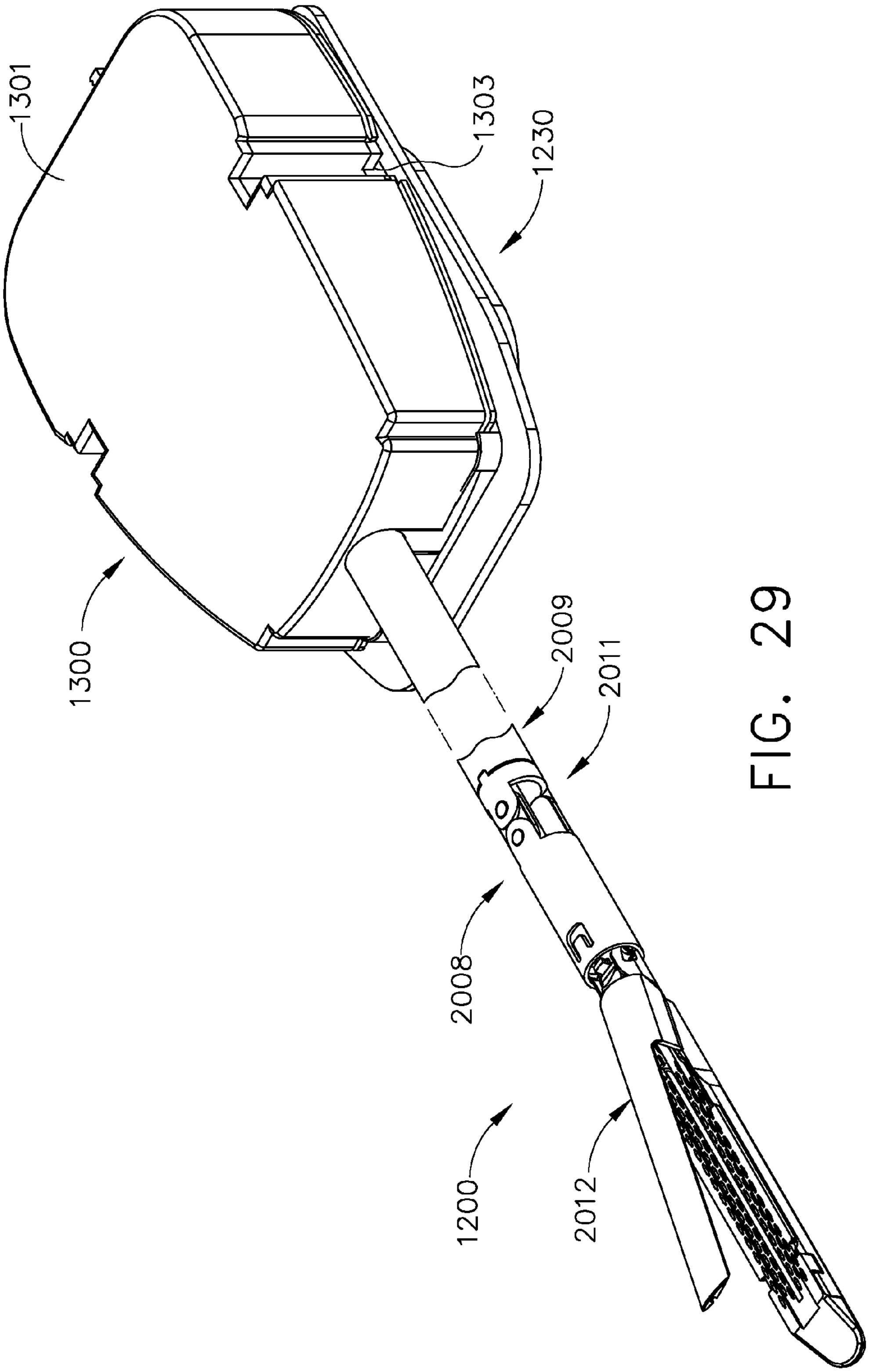


FIG. 29

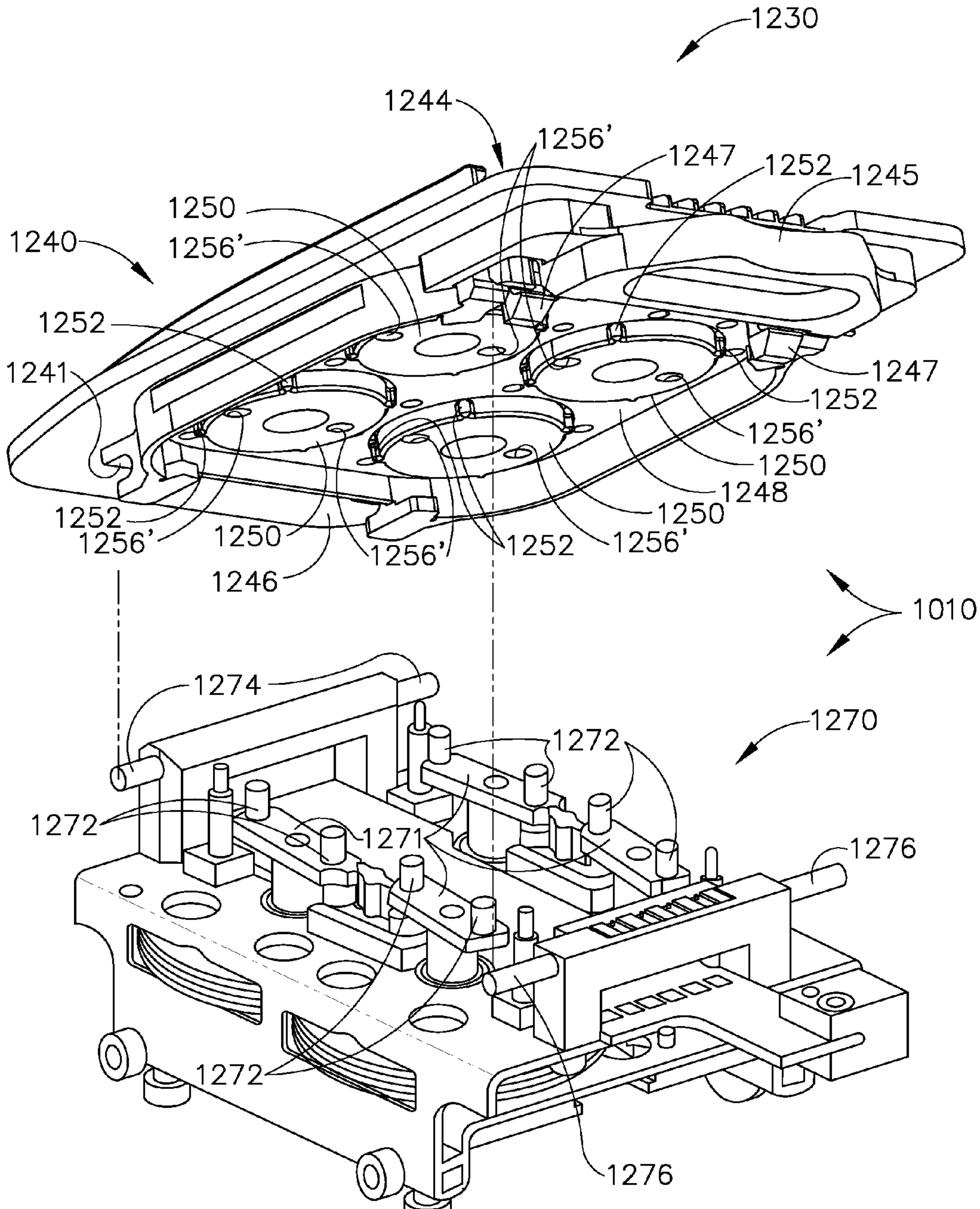

1230
1244
1256'
1247
1252
1245
1250
1256'
1240
1252
1241
1247
1252
1256'
1250
1248
1250
1252
1256'
1250
1256'
1252
1256'
1246
1010
1274
1270
1272
1272
1271
1276
1272
1276

FIG. 30

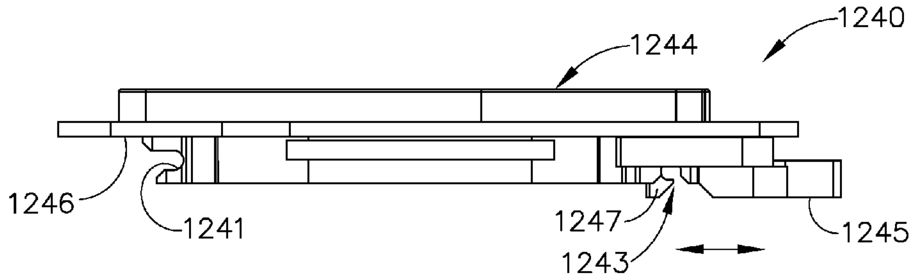

1240
1244
1246
1241
1247
1243
1245

FIG. 31

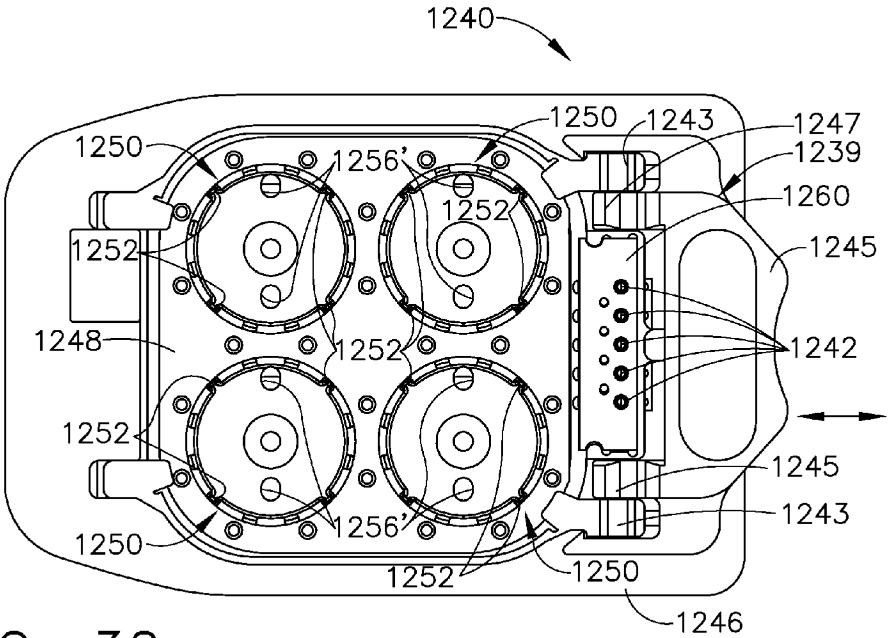

1240
1250
1243
1247
1239
1256'
1252
1260
1245
1252
1242
1248
1252
1252
1245
1243
1250
1256'
1252
1250
1246

FIG. 32

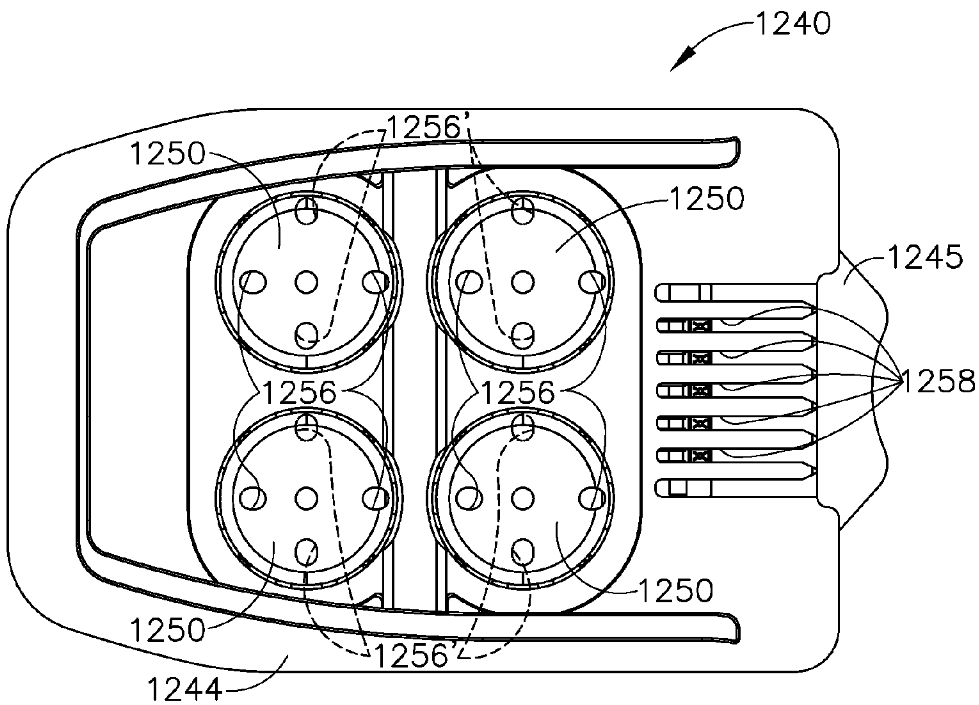


FIG. 33

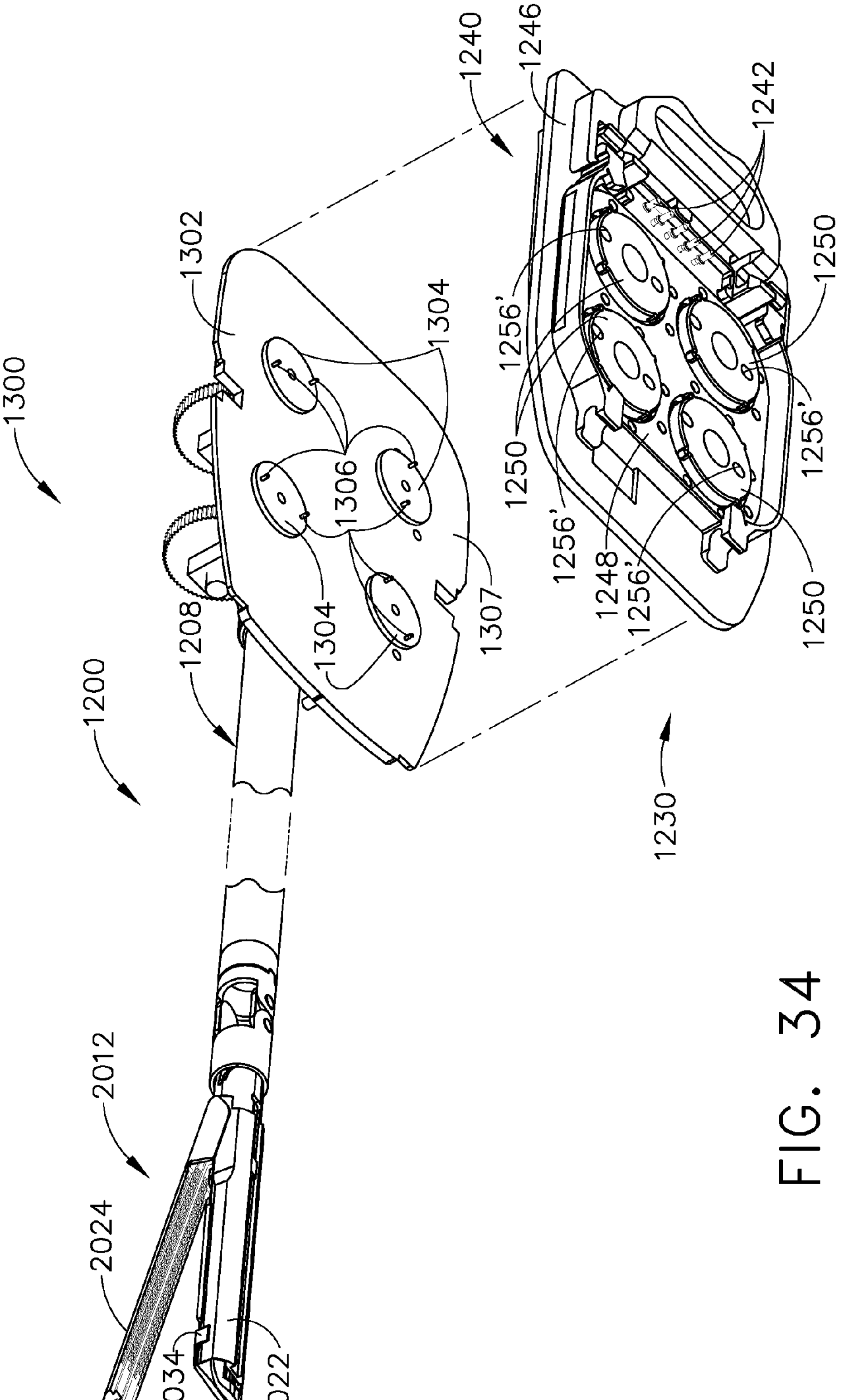

1300
1302
1304
1306
1307
1208
1200
1240
1246
1242
1250
1256'
1248
1230
2012
2024
2034
2022

FIG. 34

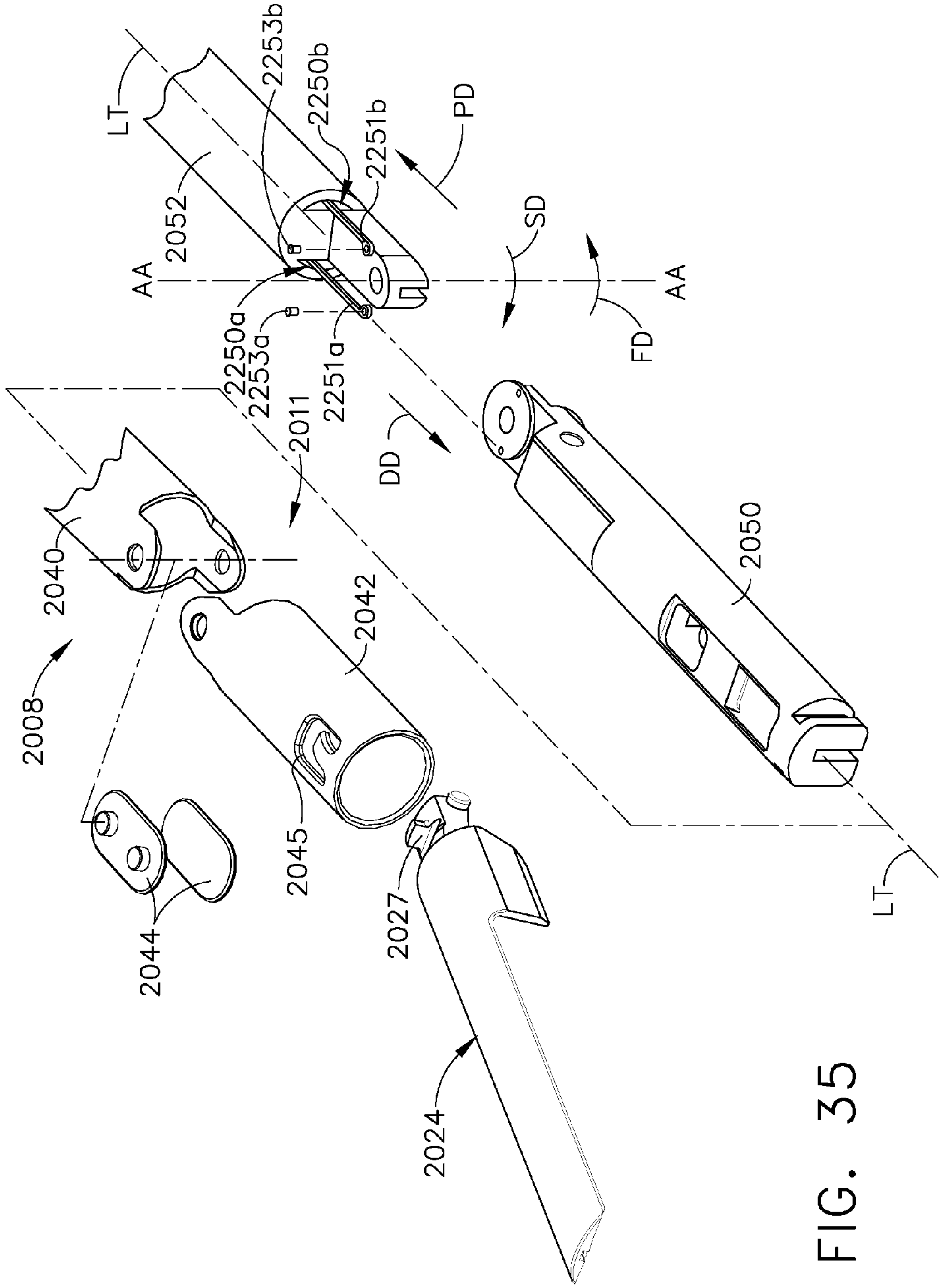

LT
2253b
2250b
2251b
PD
2052
AA
SD
AA
2250a
2253a
2251a
FD
2011
DD
2040
2050
2008
2042
2045
2044
2027
2024
LT

FIG. 35

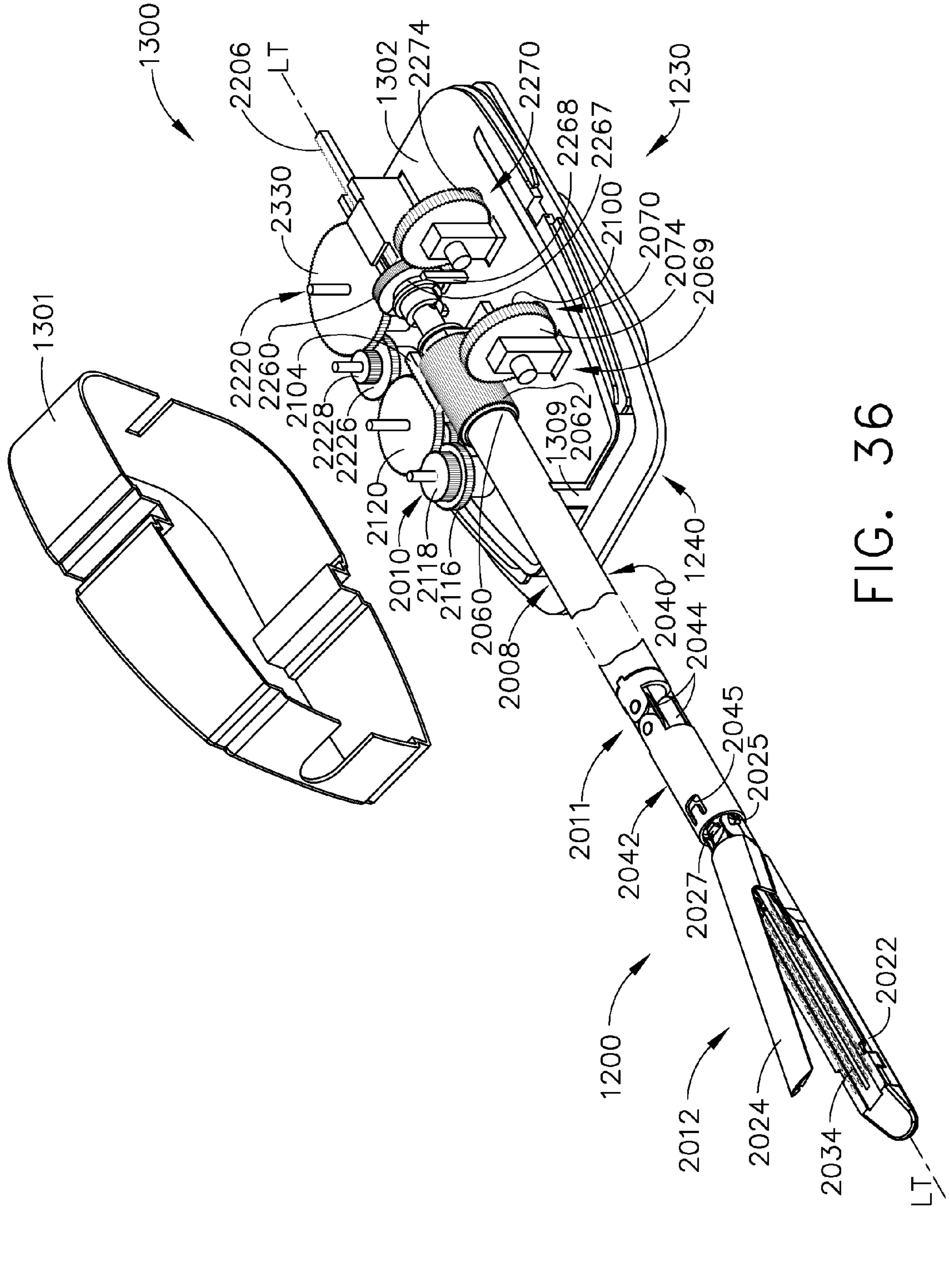

1300
2206
LT
1302
2274
2270
1230
2268
2267
2330
2100
2070
2074
2069
1301
2220
2260
2104
2228
2226
1309
2062
2120
2010
2118
2116
2060
1240
2040
2044
2008
2045
2025
2011
2042
2027
2022
1200
2012
2024
2034
LT

FIG. 36

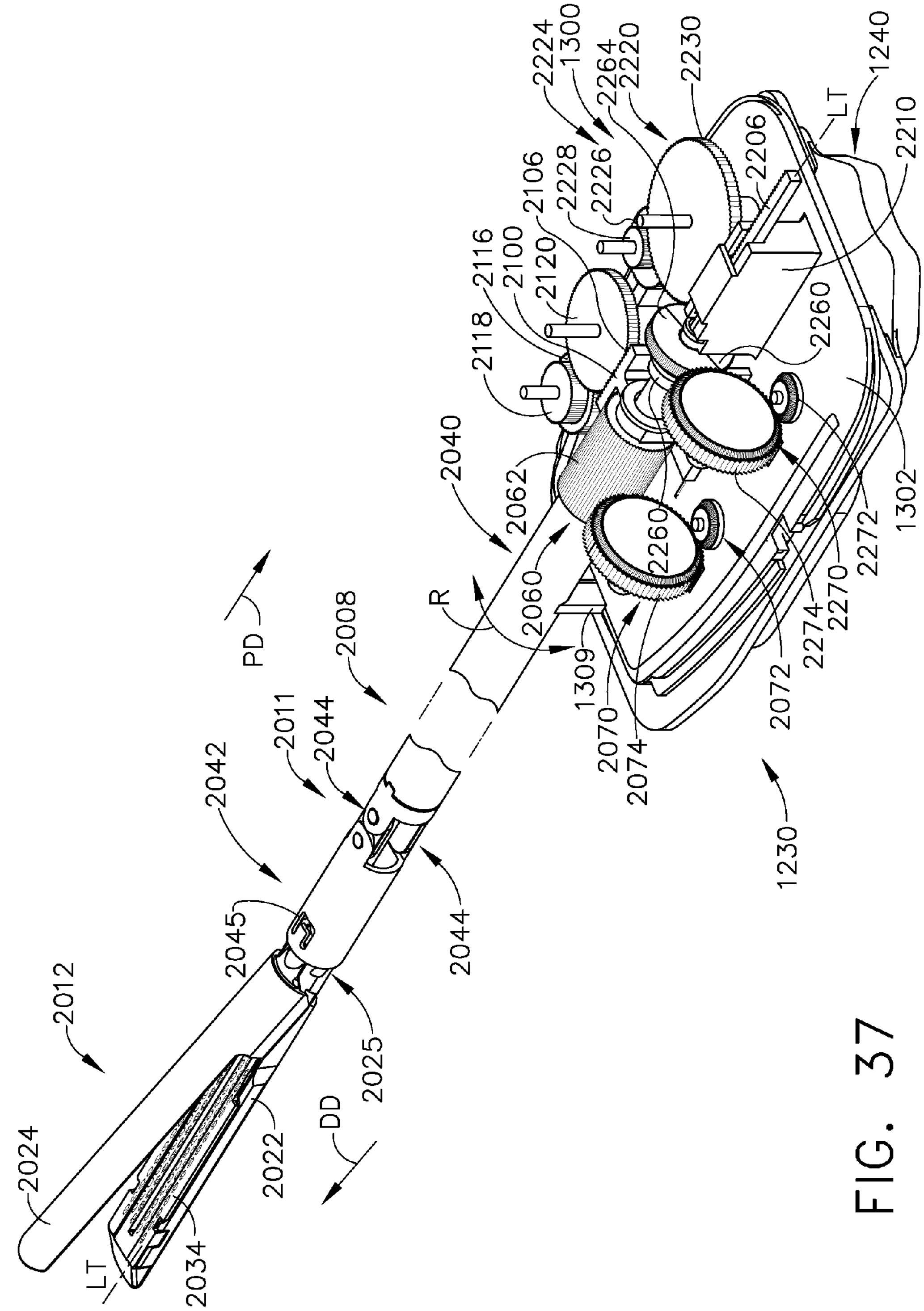
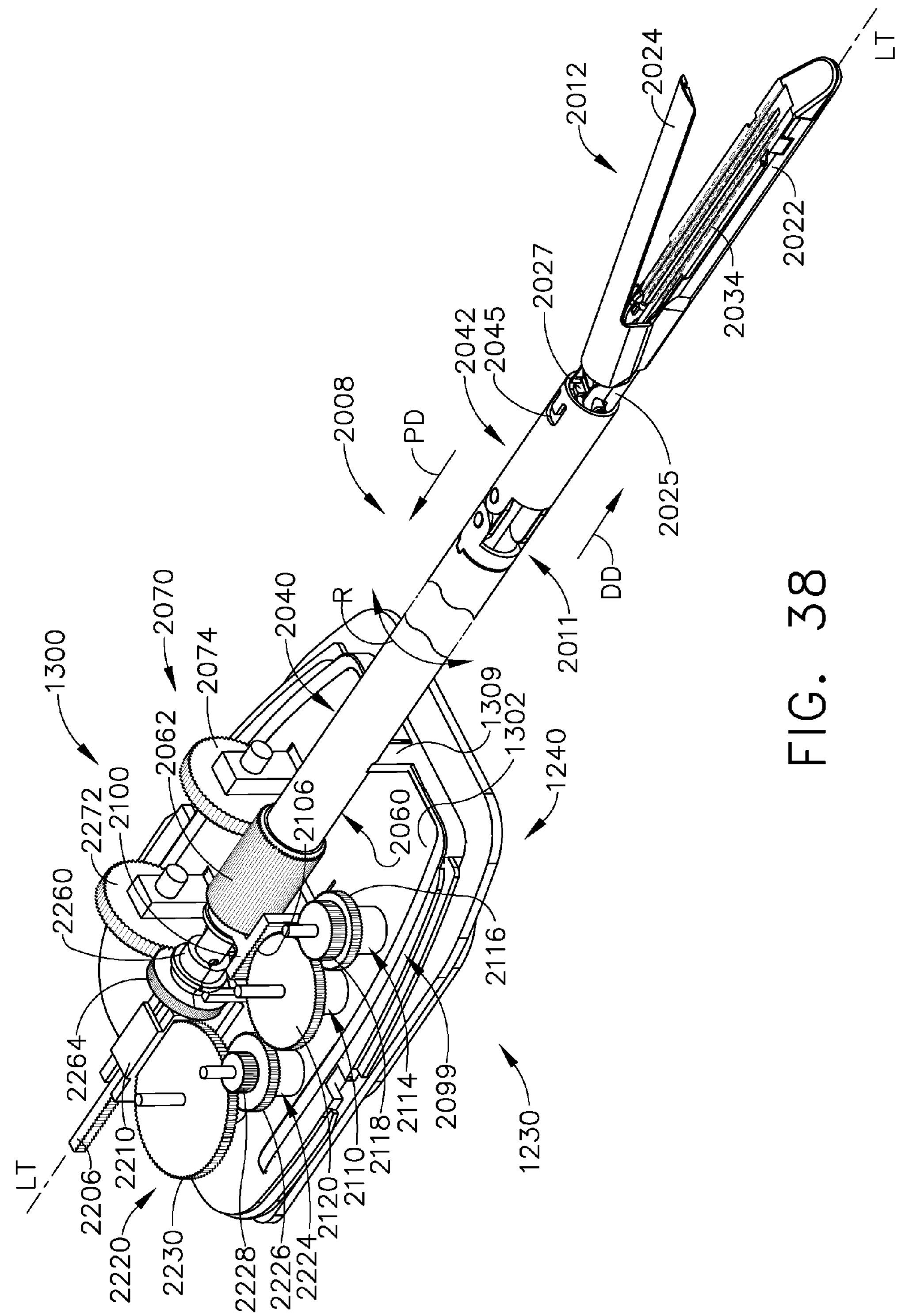

2224
1300
2264
2220
2230
1240
2210
LT
2206
2228
2226
2106
2116
2100
2120
2118
2260
2040
2062
2060
R
PD
2008
2011
2044
2042
2045
2012
2024
2025
2022
DD
2034
LT
1309
2070
2074
2072
2274
2270
2272
1302
1230

FIG. 37



LT
2024
2012
2022
2034
2027
2042
2045
2008
PD
2025
DD
2011
R
2040
2070
2074
1300
2062
1309
1302
1240
2272
2100
2106
2060
2260
2116
2264
2099
2114
2118
2110
2120
1230
LT
2206
2210
2220
2230
2228
2226
2224

FIG. 38

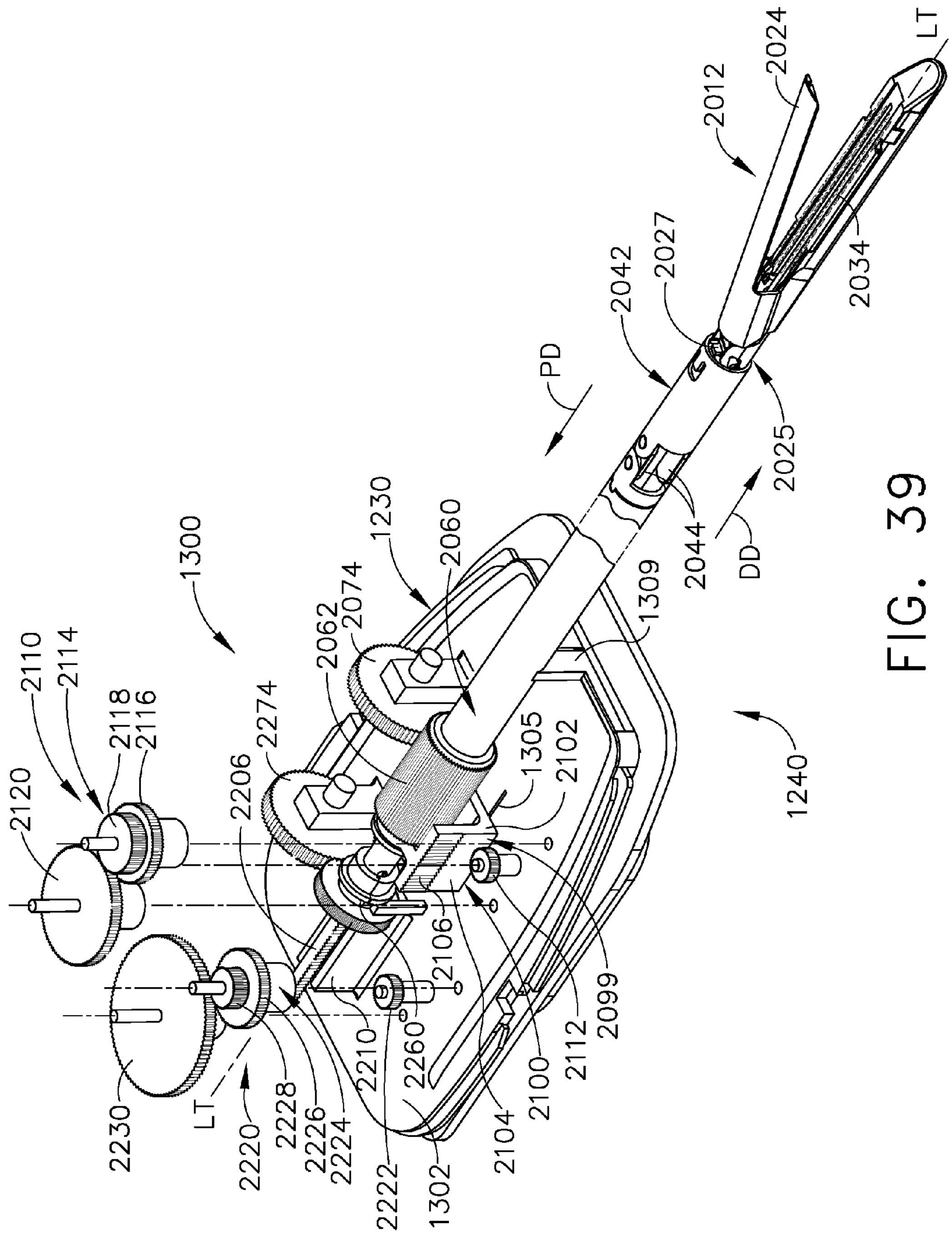

2024
LT
2012
2027
2042
2034
PD
2025
2044
DD
1230
2060
1300
2074
2062
1309
2110
2114
2118
2116
2274
2206
1305
2102
2120
1240
2106
2099
2112
2100
2104
2210
2260
2222
1302
2224
2226
2228
2220
LT
2230

FIG. 39

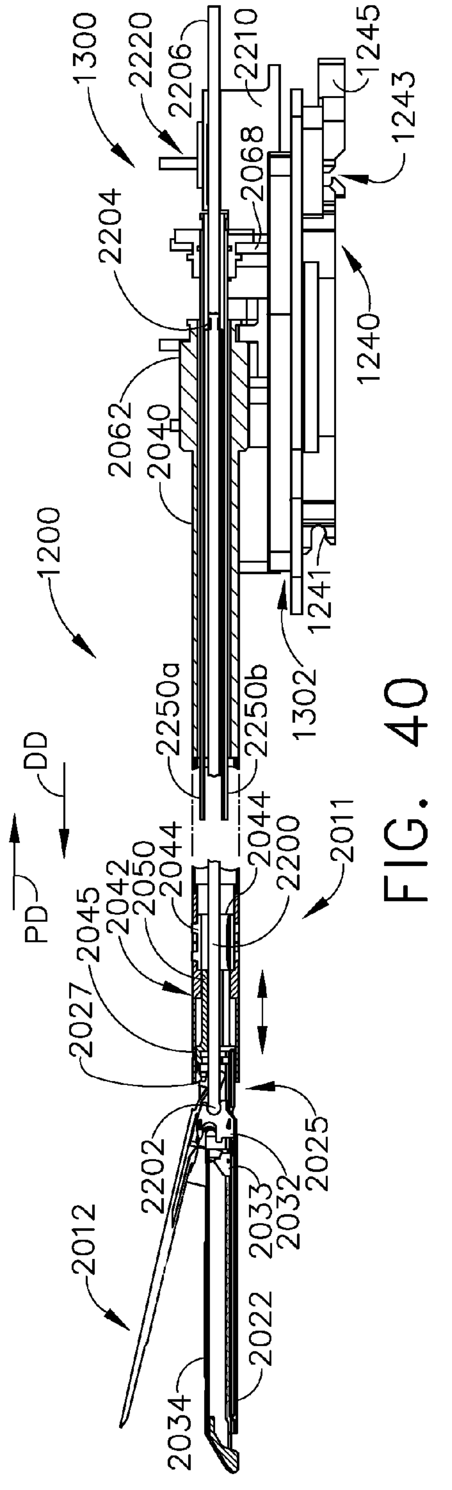

1300
2220
2206
2210
1245
1243
2068
2204
1240
2062
2040
1200
1241
1302
2250a
2250b
DD
PD
2044
2200
2011
2045
2042
2050
2027
2025
2202
2033
2032
2012
2022
2034

FIG. 40

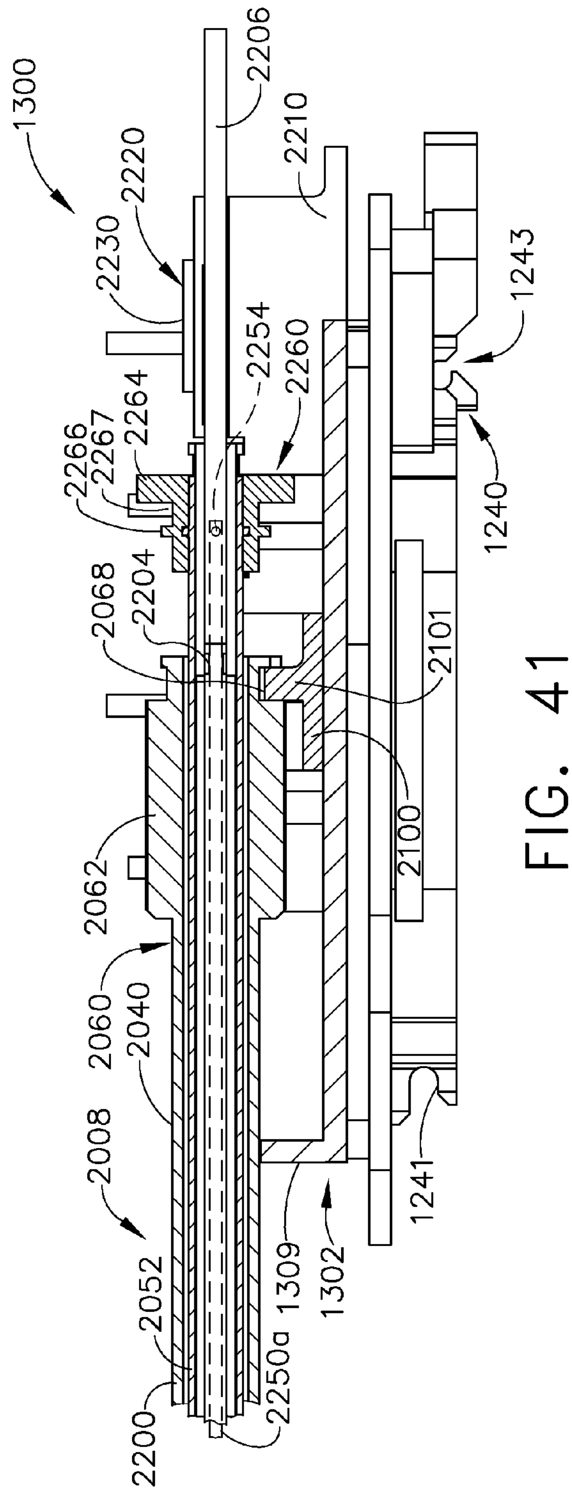

1300
2206
2210
2220
2230
1243
2254
2260
2264
2267
2266
1240
2068
2204
2101
2100
2062
2060
2040
2008
2052
2200
2250a
1309
1302
1241

FIG. 41

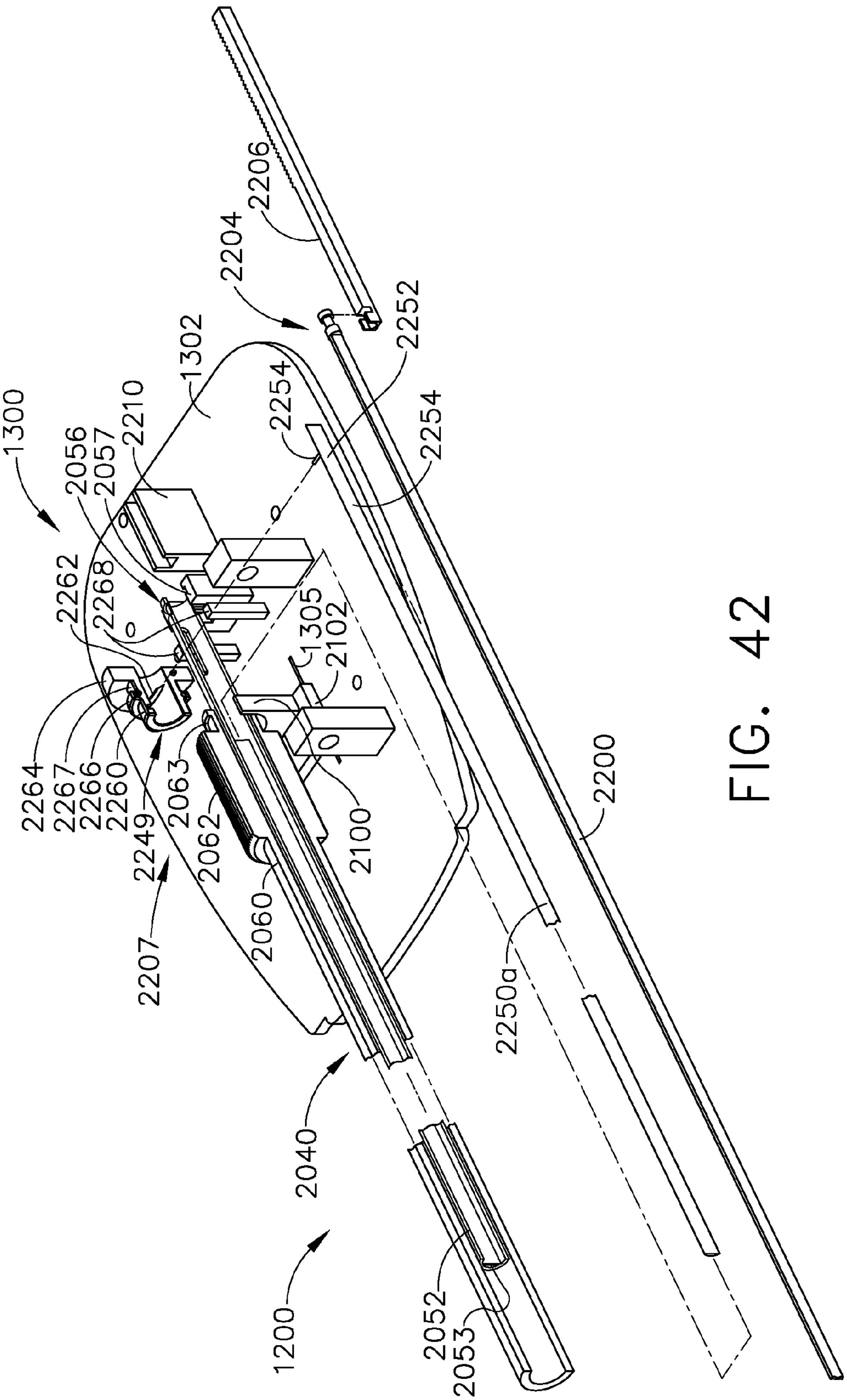

1300
1302
2210
2056
2057
2262
2268
2264
2267
2266
2260
2249
2207
2063
2062
2060
2100
2102
1305
2204
2206
2252
2254
2254
2200
2250a
2040
1200
2052
2053

FIG. 42

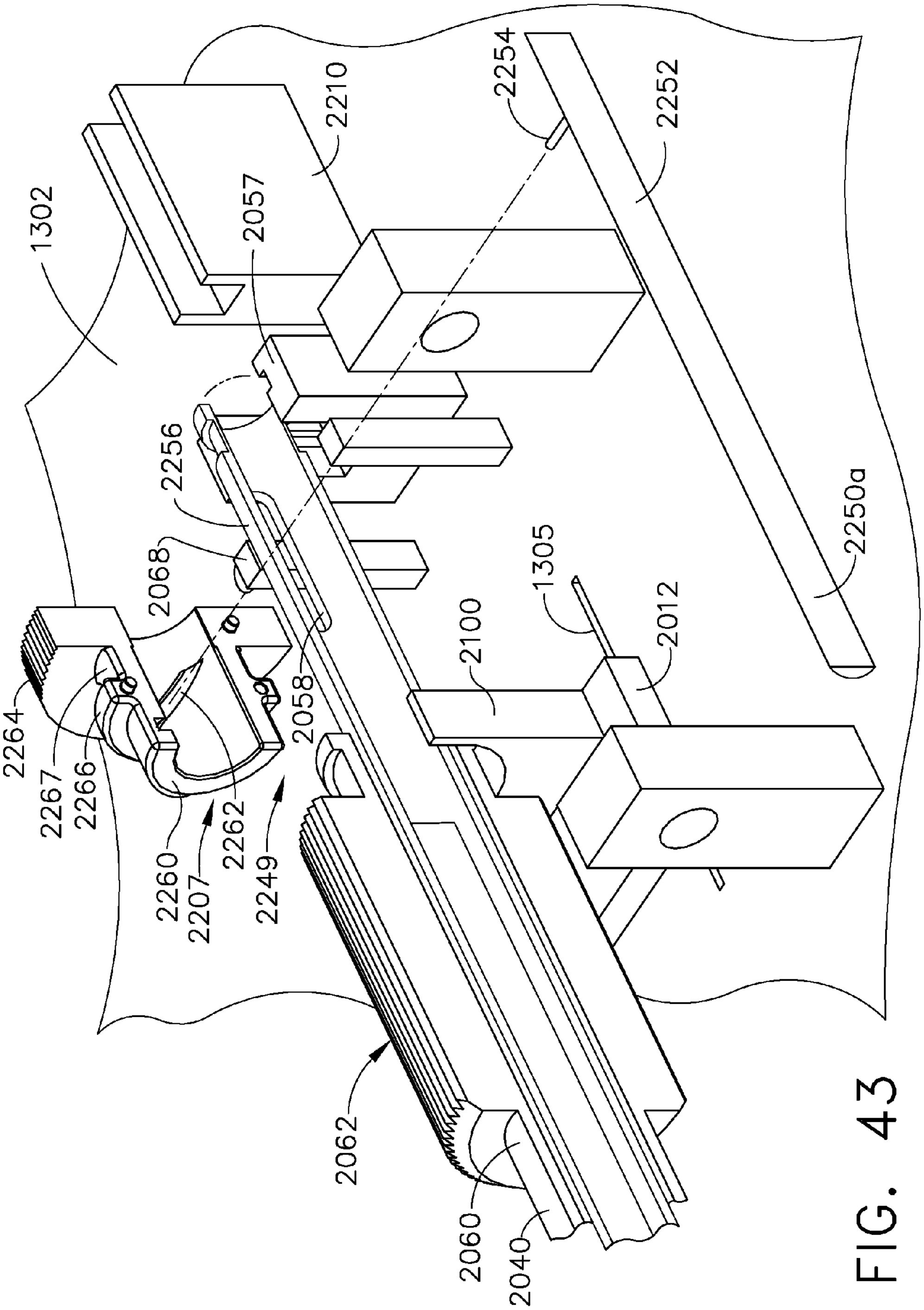

1302
2210
2254
2252
2057
2256
2250a
2068
1305
2100
2012
2058
2264
2267
2266
2262
2260
2207
2249
2062
2060
2040

FIG. 43

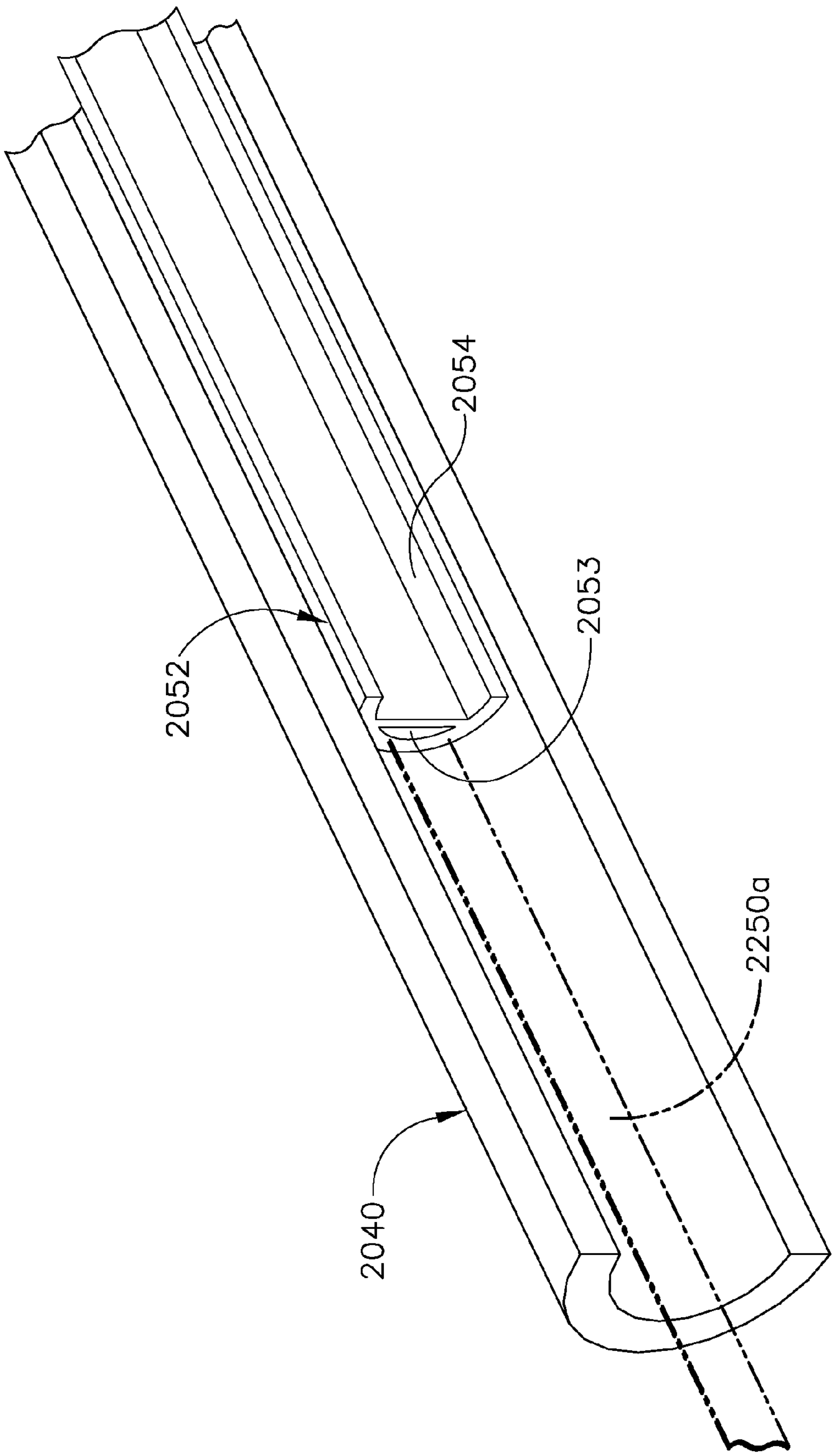


FIG. 44

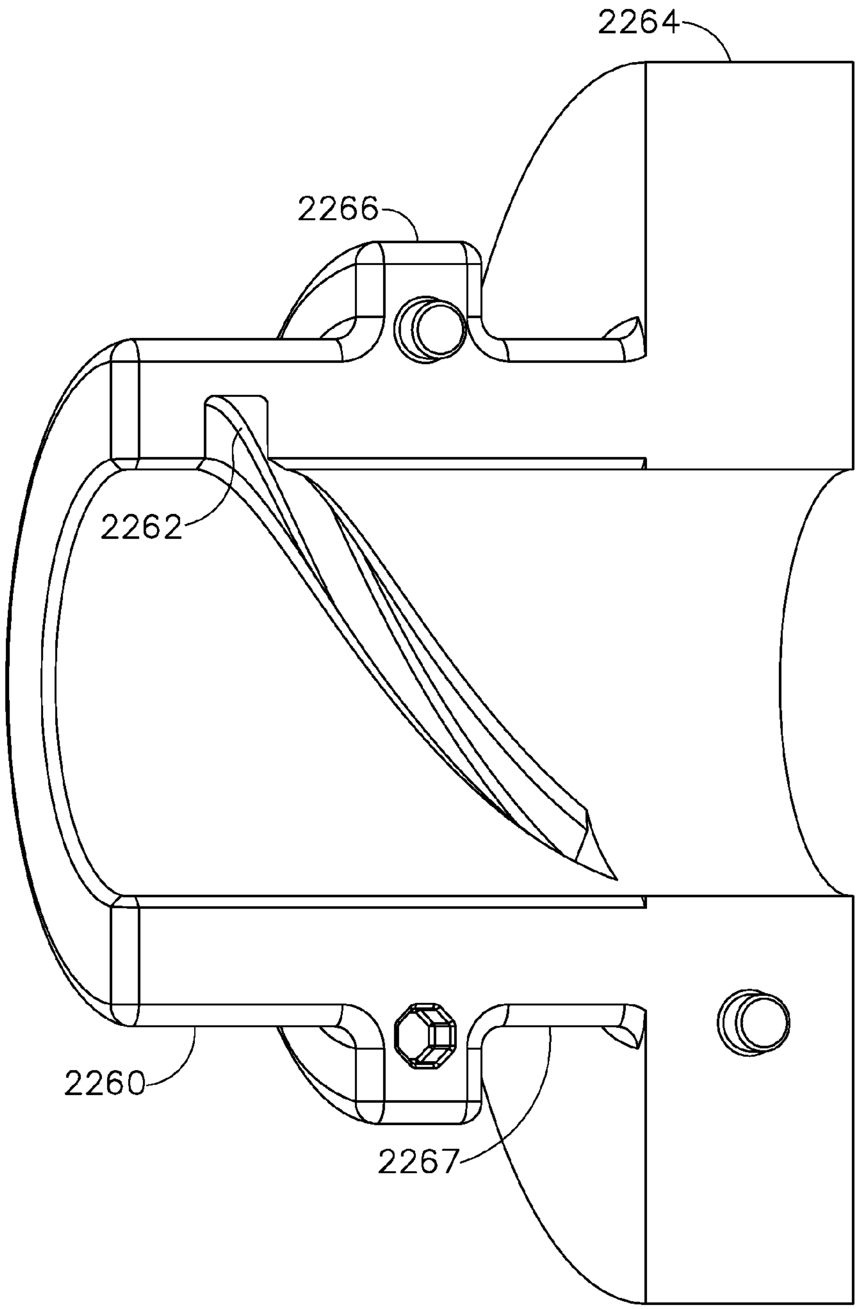


FIG. 45

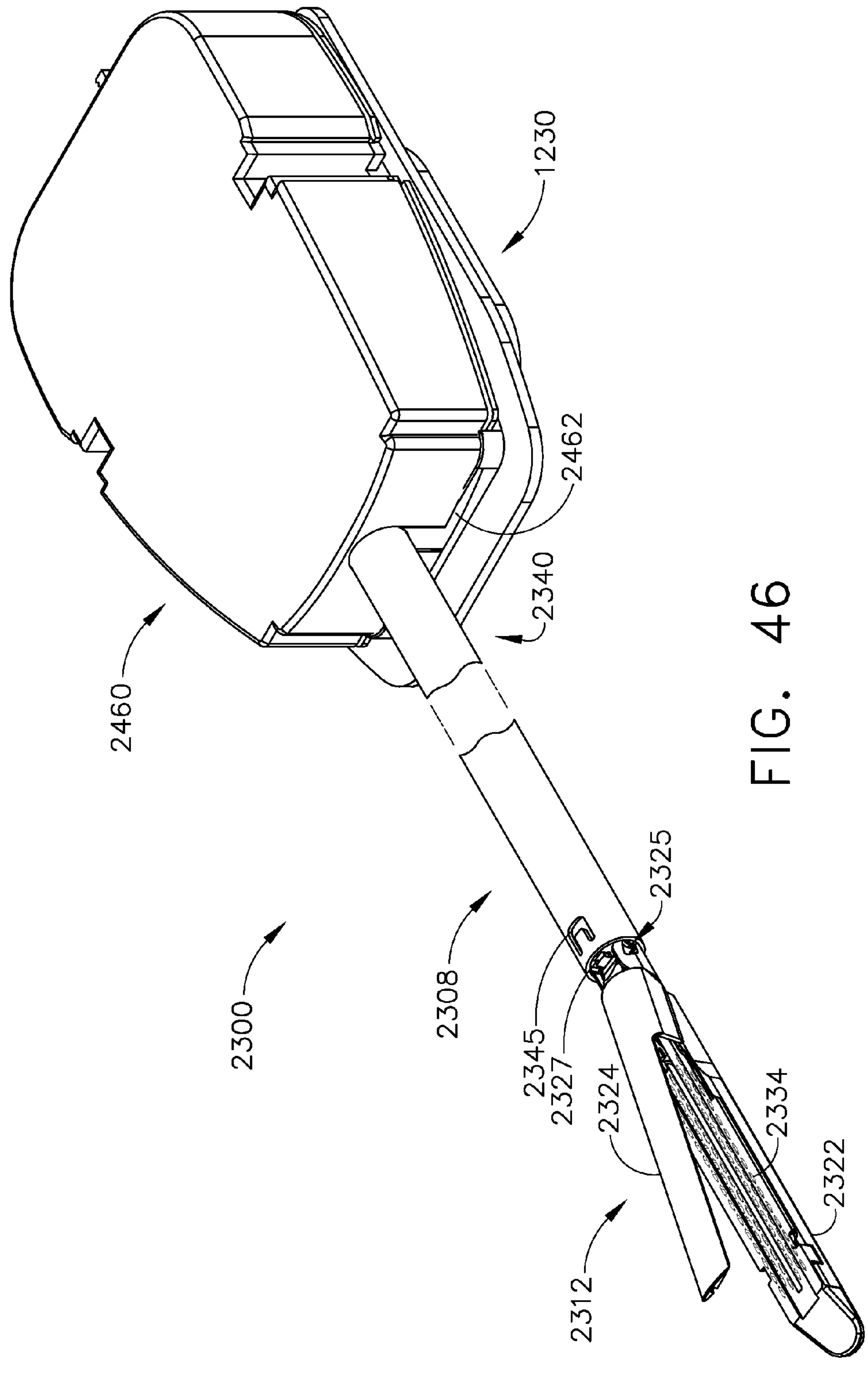

1230
2462
2340
2460
2300
2308
2325
2345
2327
2324
2334
2322
2312

FIG. 46

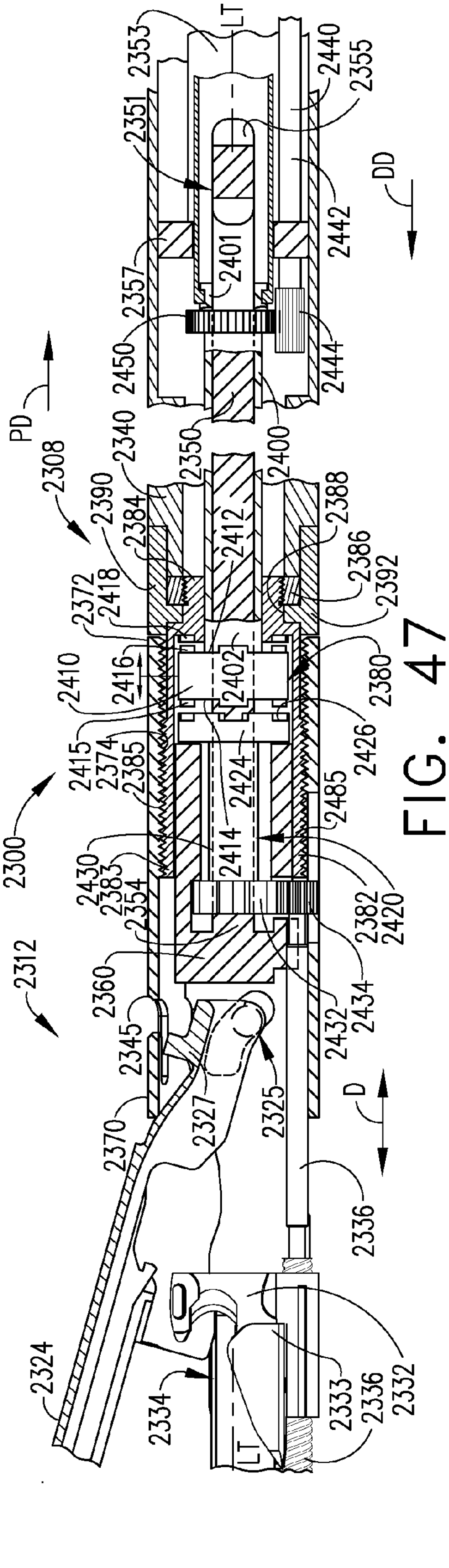


FIG. 47

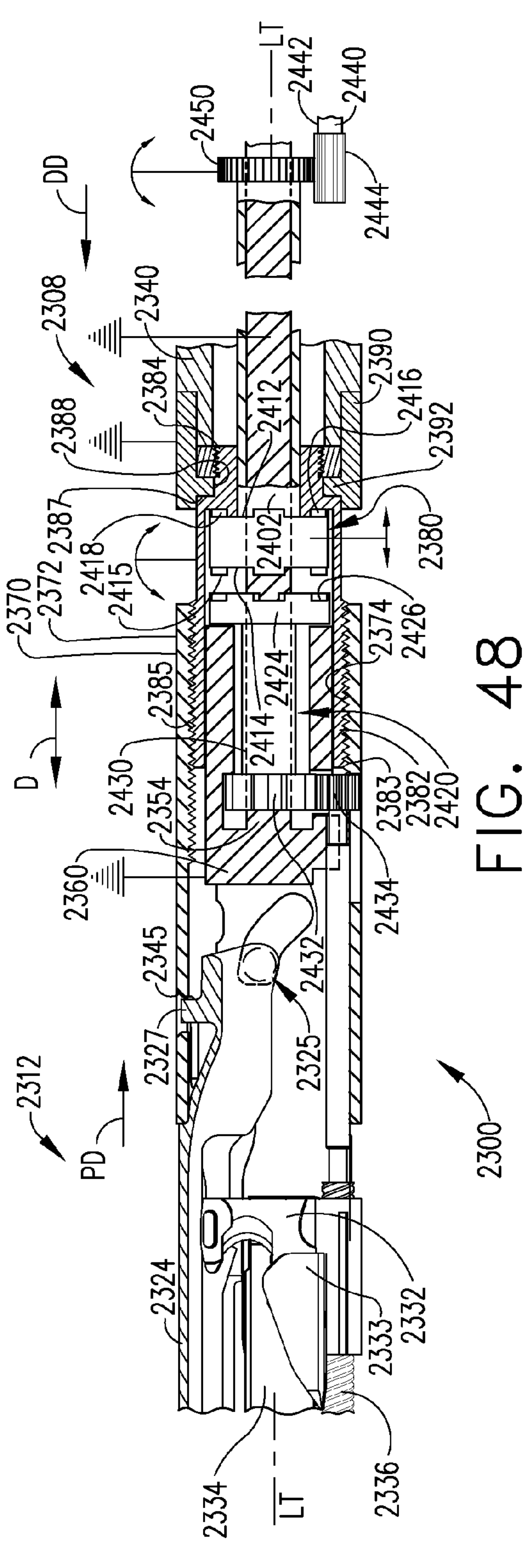


FIG. 48

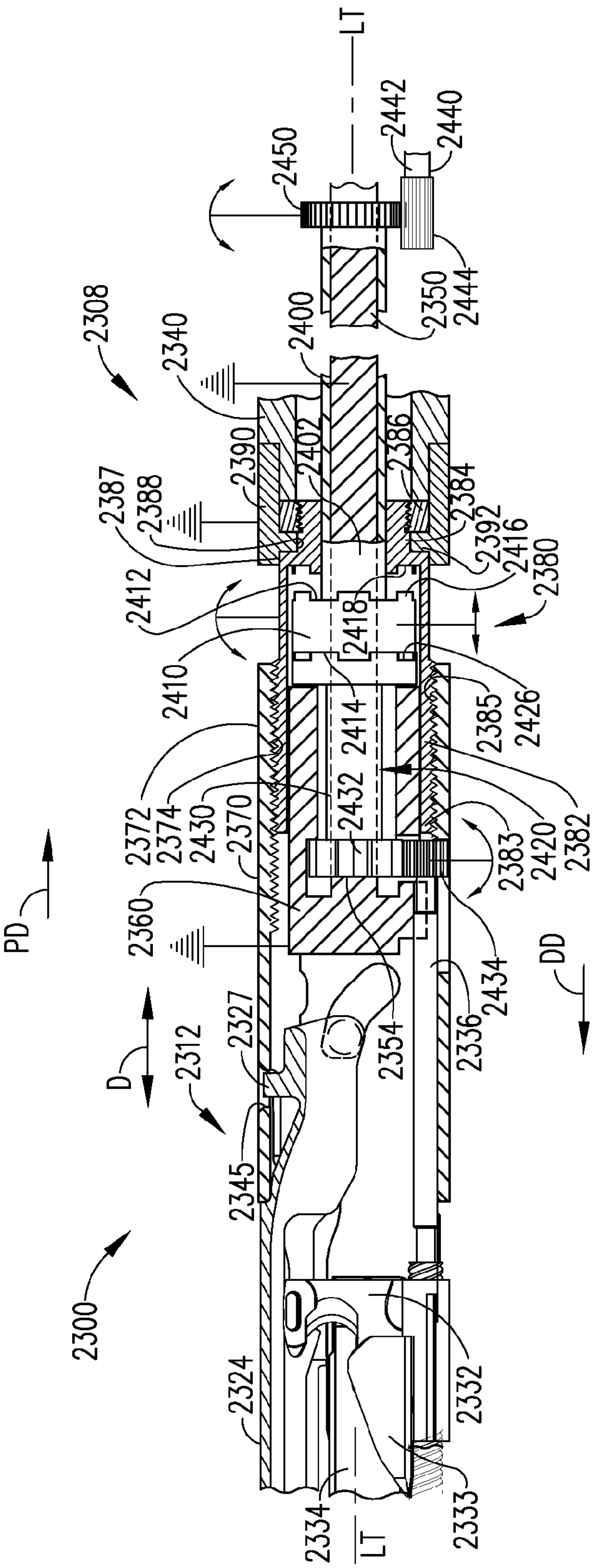

LT
2442
2440
2450
2444
2350
2400
2308
2340
2390
2402
2386
2384
2387
2388
2392
2416
2380
2412
2418
2410
2414
2385
2426
2372
2374
2430
2370
2432
2420
2382
2383
2360
2434
PD
DD
2336
2354
2327
2312
D
2345
2300
2324
2332
2334
LT
2333

FIG. 49

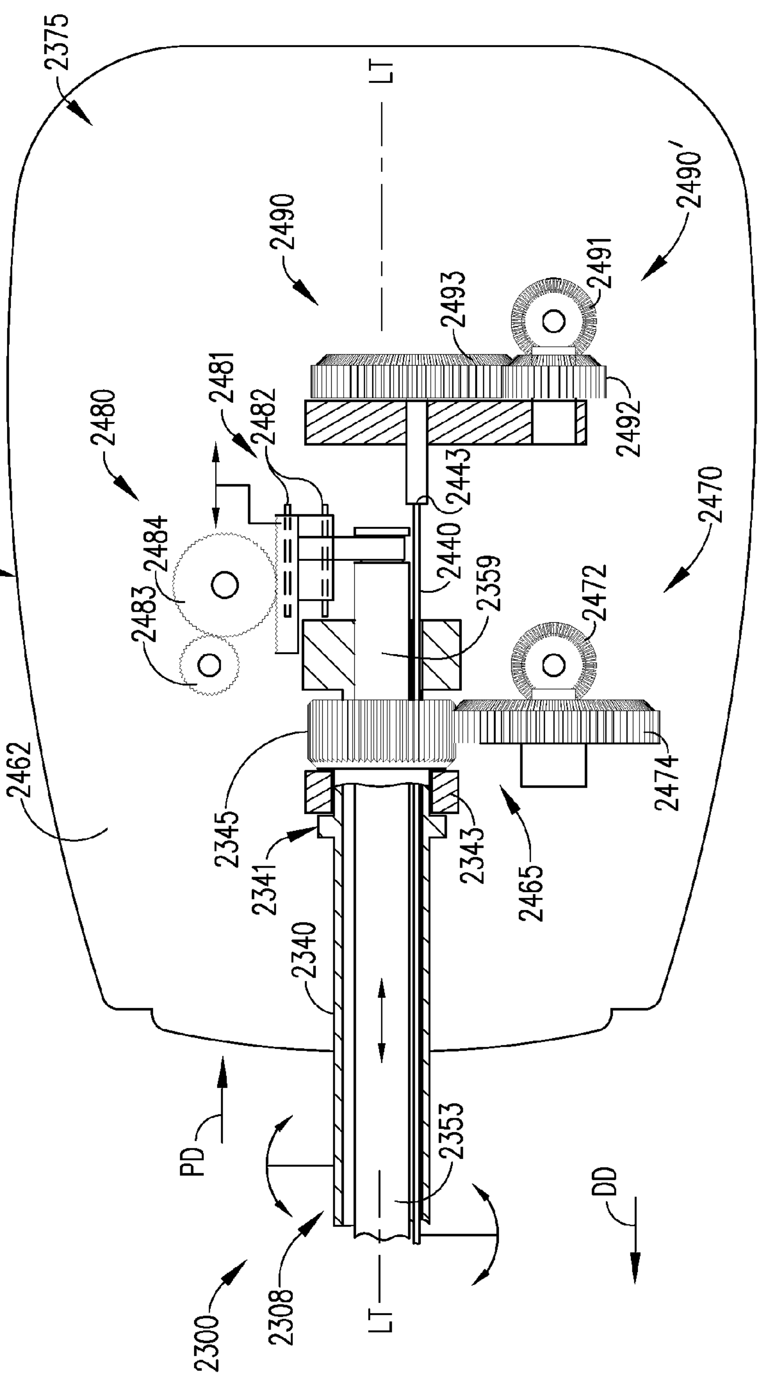

2375
LT
2490
2490′
2491
2493
2492
2481
2482
2480
2443
2440
2470
2460
2484
2483
2359
2472
2462
2345
2474
2341
2343
2465
2340
2353
PD
DD
2300
2308
LT

FIG. 50

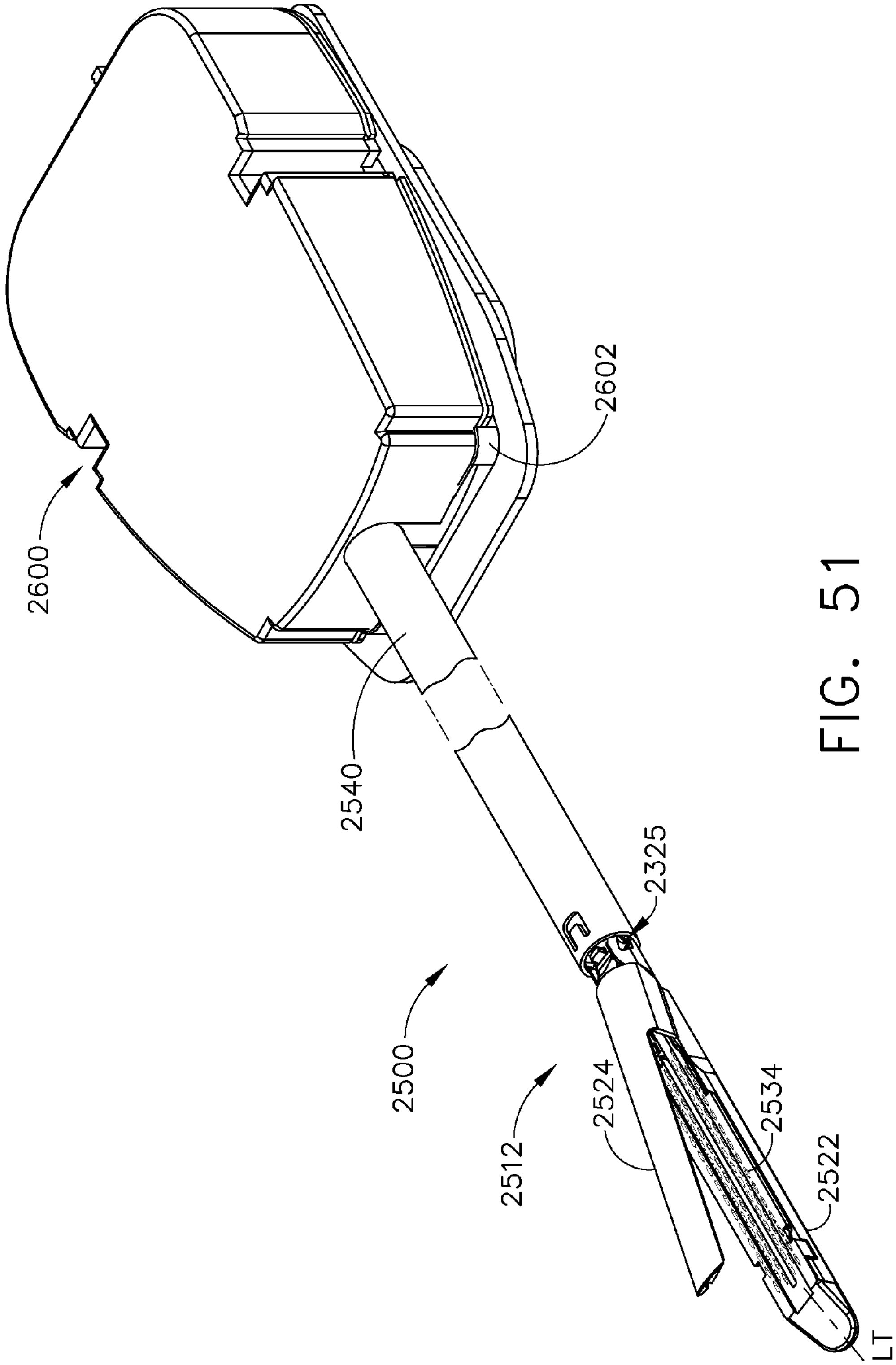


FIG. 51

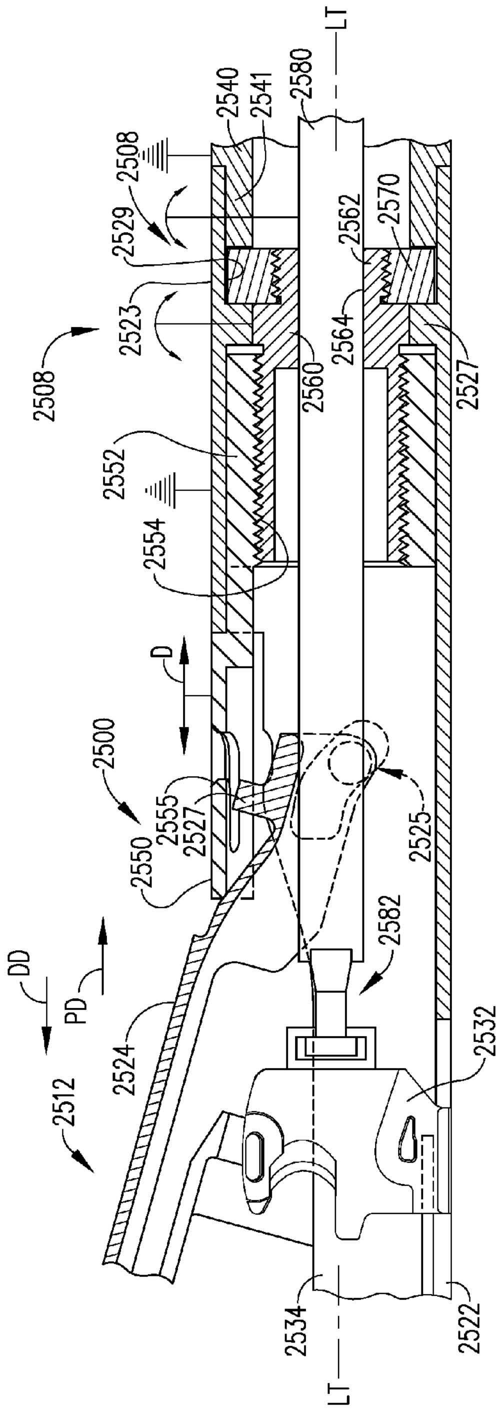

2508
2529
2523
2540
2541
2580
LT
2562
2570
2564
2560
2527
2552
2554
D
2500
2555
2550
2525
2582
2524
2512
DD
PD
2532
2534
2522

FIG. 52

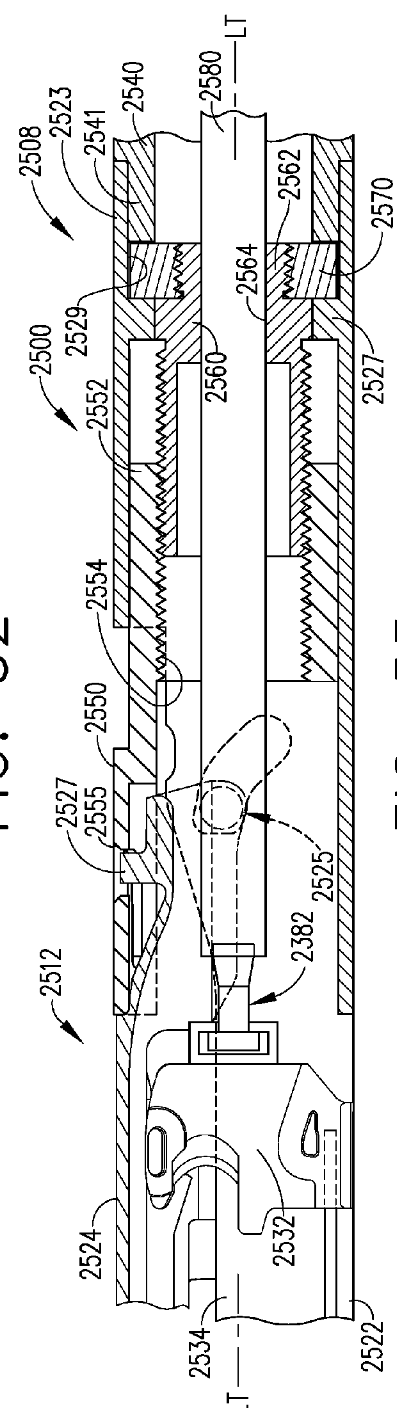

2508
2523
2541
2540
2580
LT
2562
2570
2564
2529
2500
2552
2560
2527
2554
2550
2555
2525
2382
2512
2524
2532
2534
2522

FIG. 53

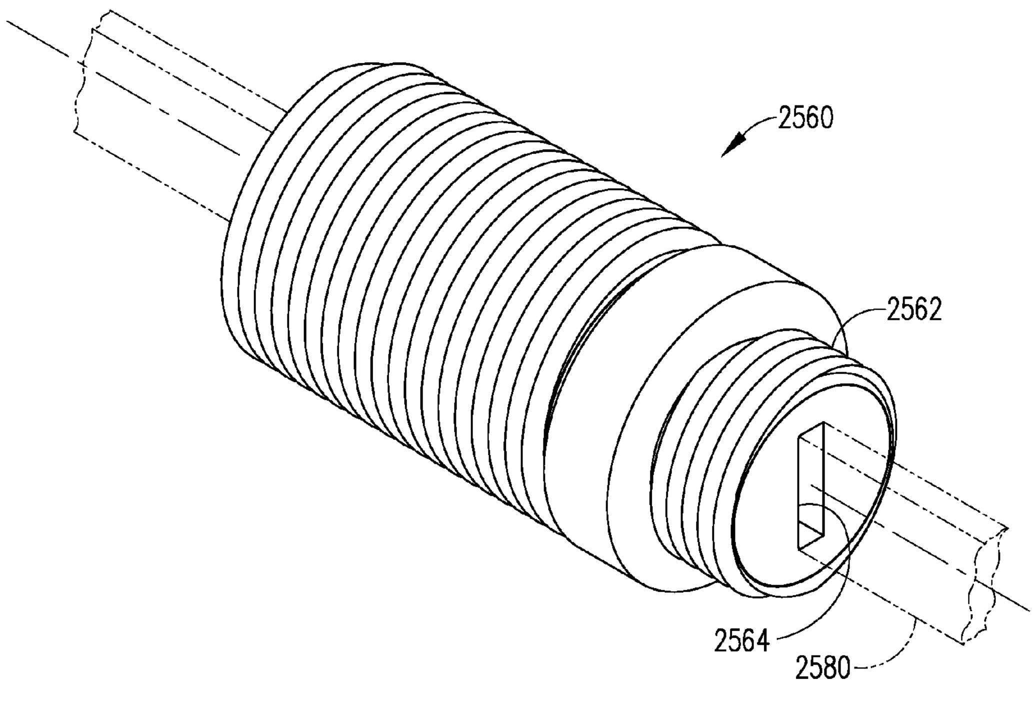


FIG. 54

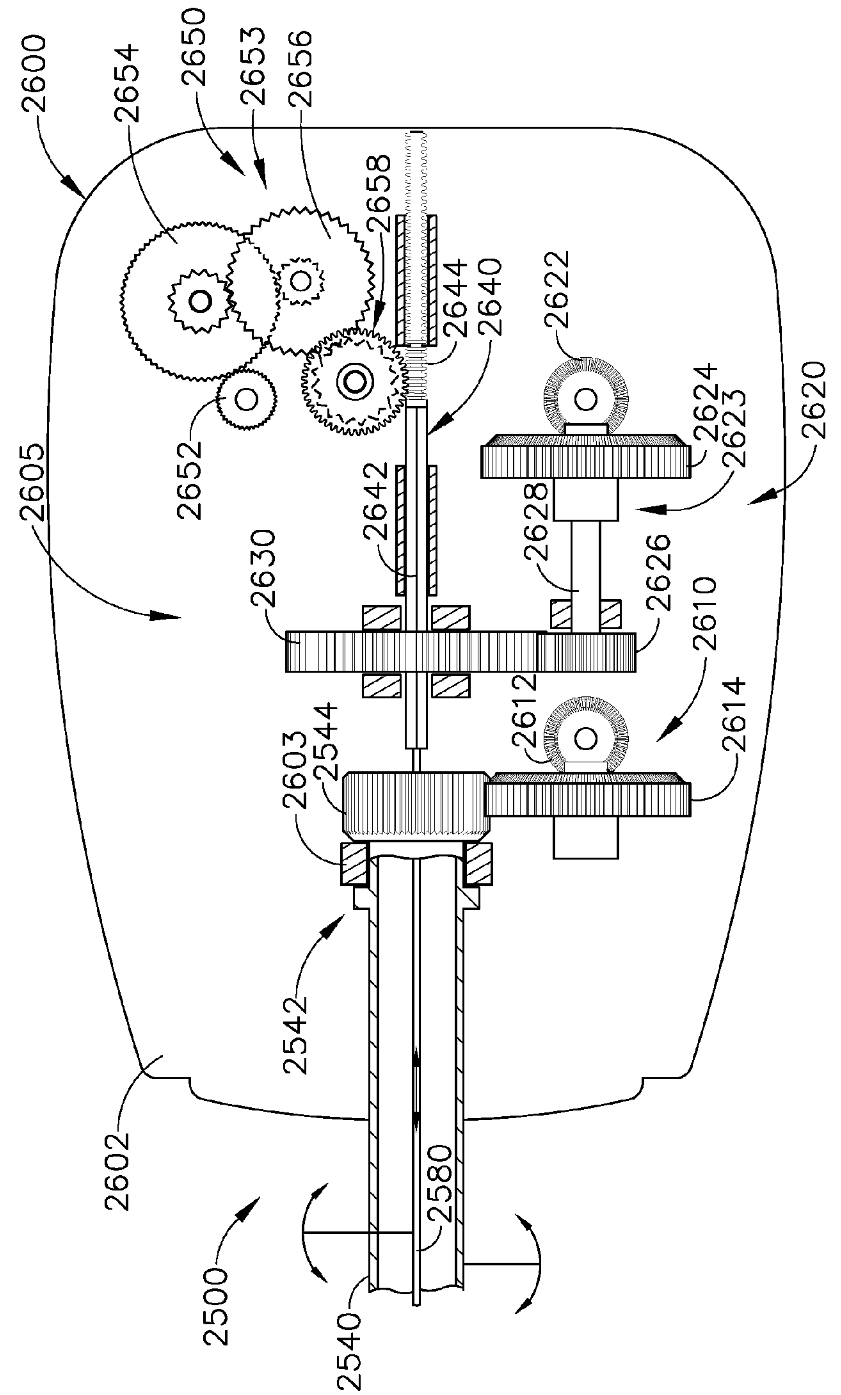

2600
2654
2650
2653
2656
2658
2644
2640
2622
2624
2623
2620
2652
2605
2642
2628
2626
2630
2610
2612
2614
2603
2544
2542
2602
2580
2500
2540

FIG. 55

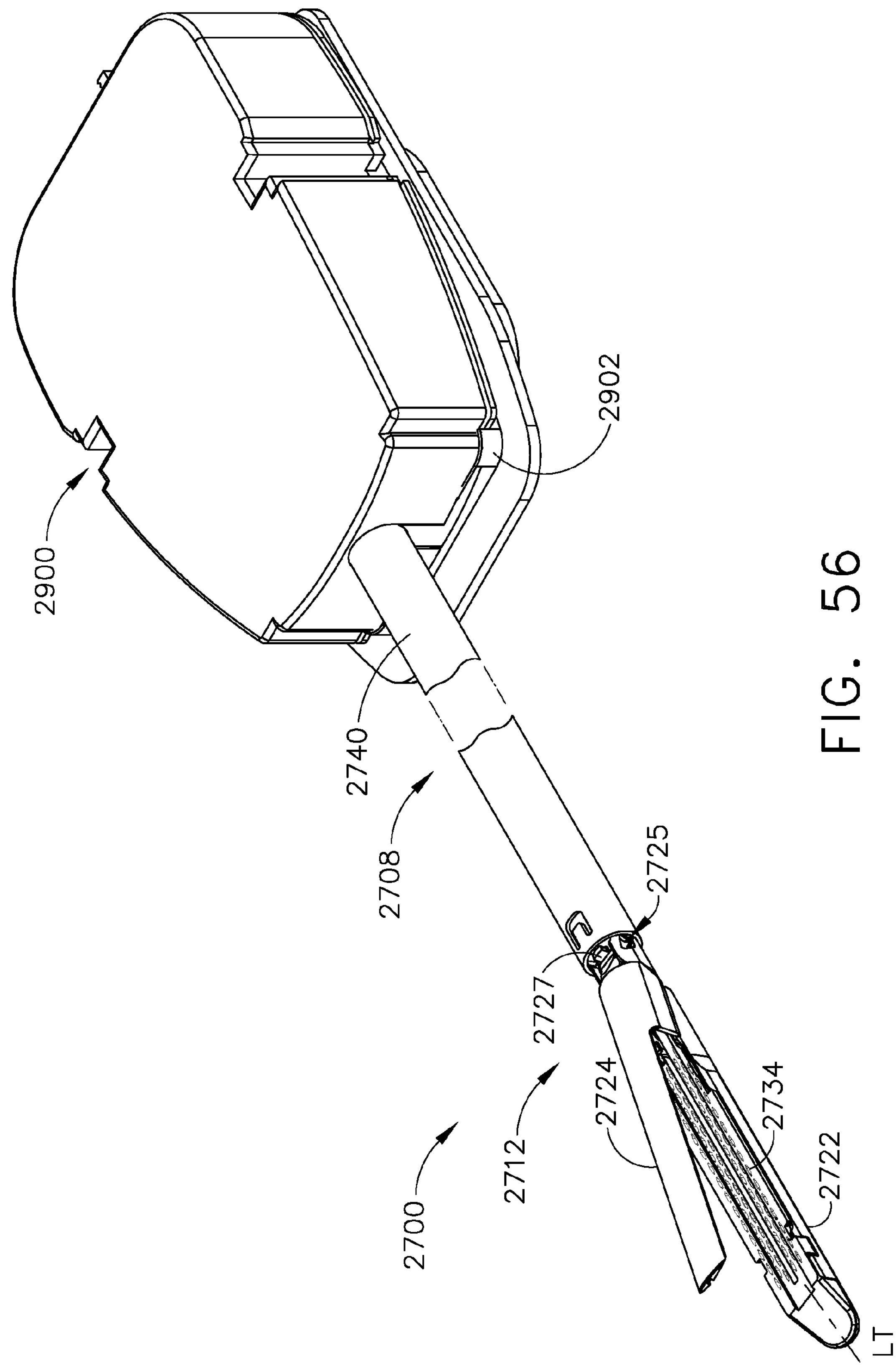
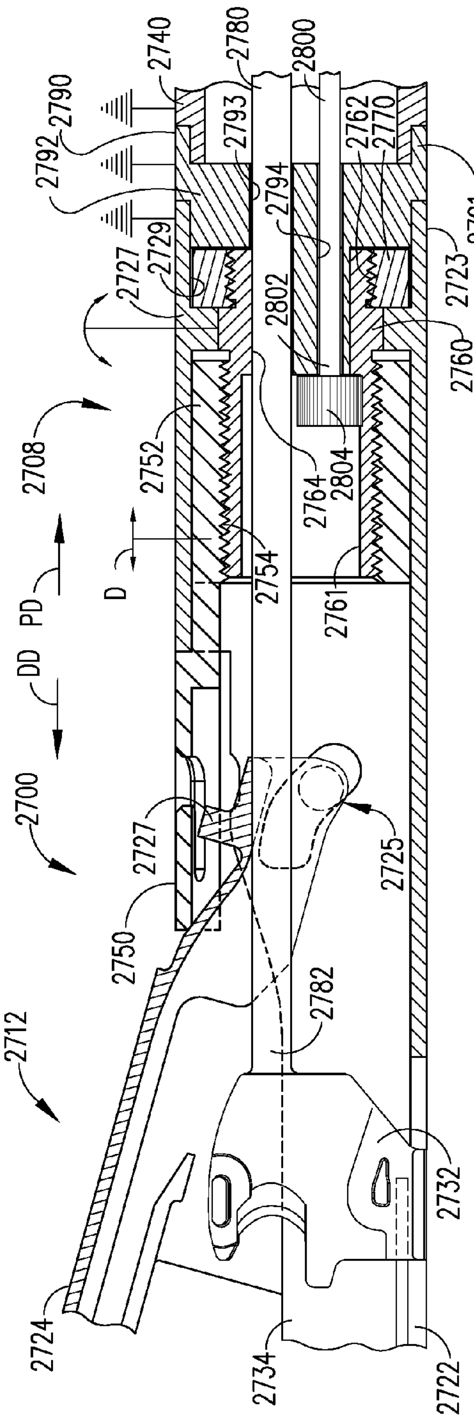


FIG. 56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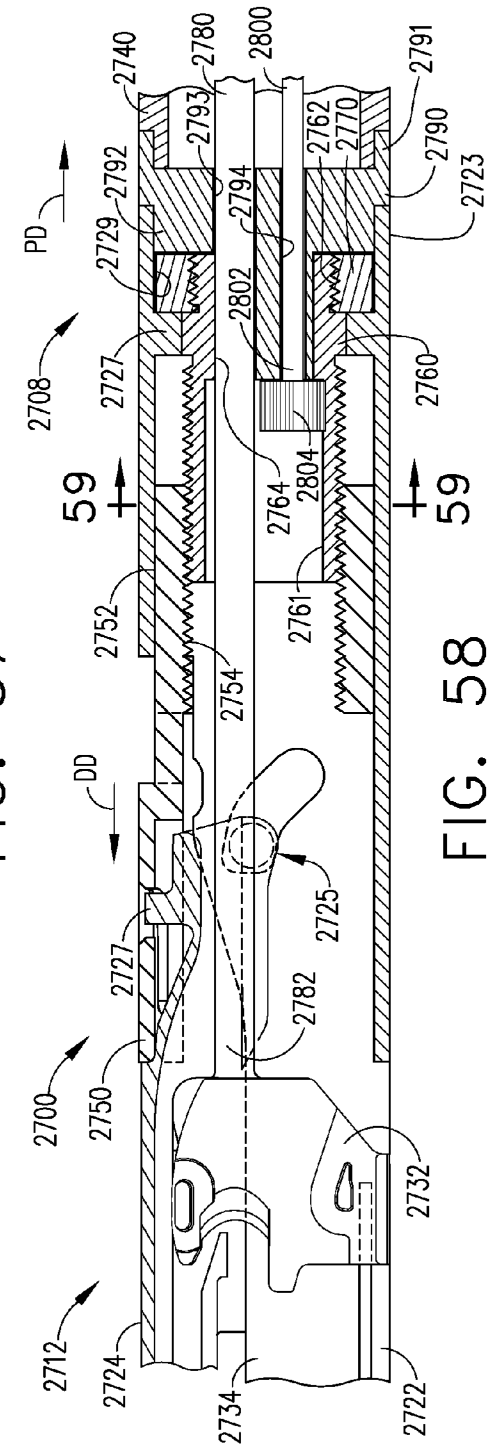
2793
2762
2770
2794
2791
2727
2729
2723
2802
2760
2708
2752
2764
2804
2754
PD
D
DD
2761
2700
2725
2750
2782
2712
2732
2724
2734
2722

FIG. 57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2792
2794
2723
PD
2729
2727
2802
2760
2708
59
2764
2804
59
2752
2761
2754
DD
2725
2727
2782
2700
2750
2732
2712
2724
2734
2722

FIG. 58

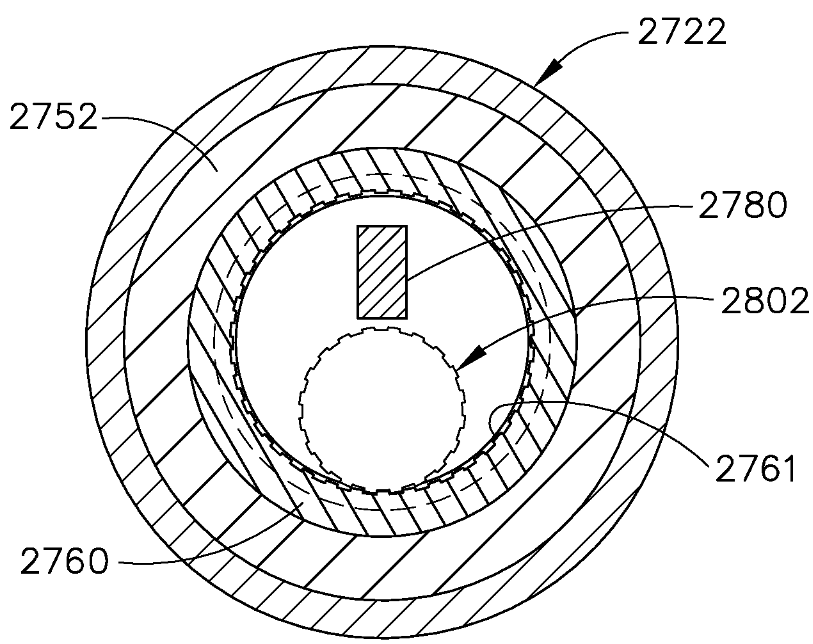


FIG. 59

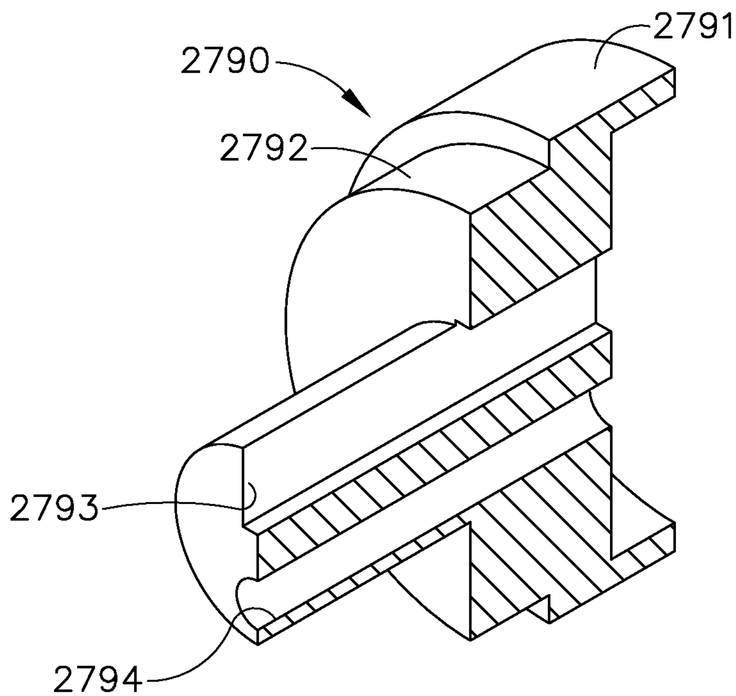


FIG. 60

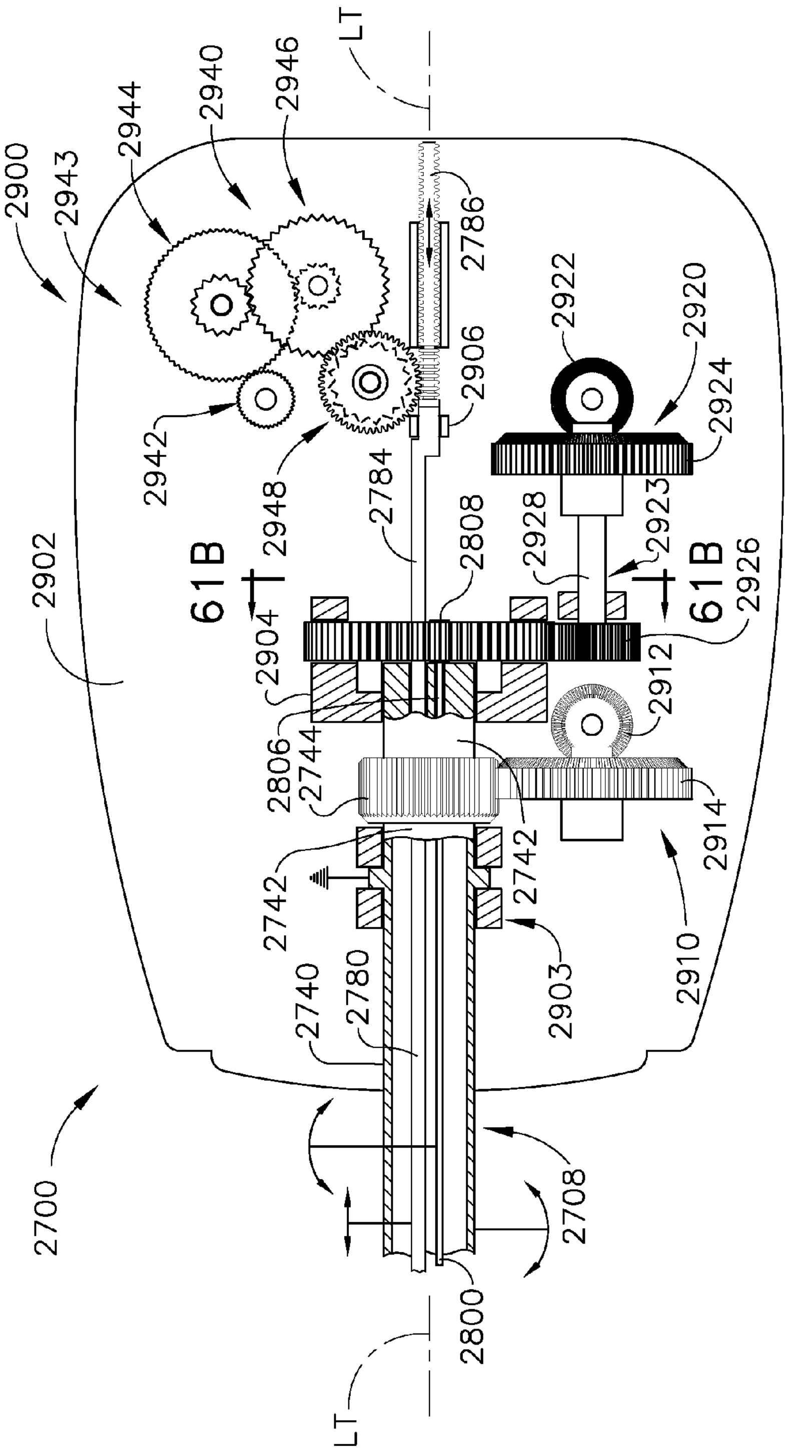

LT
2900
2943
2944
2940
2946
2786
2922
2920
2924
2906
2942
2948
2784
2928
2923
61B
2808
2902
2926
2904
2912
2806
2744
2742
2914
2740
2780
2903
2910
2700
2708
2800

FIG. 61

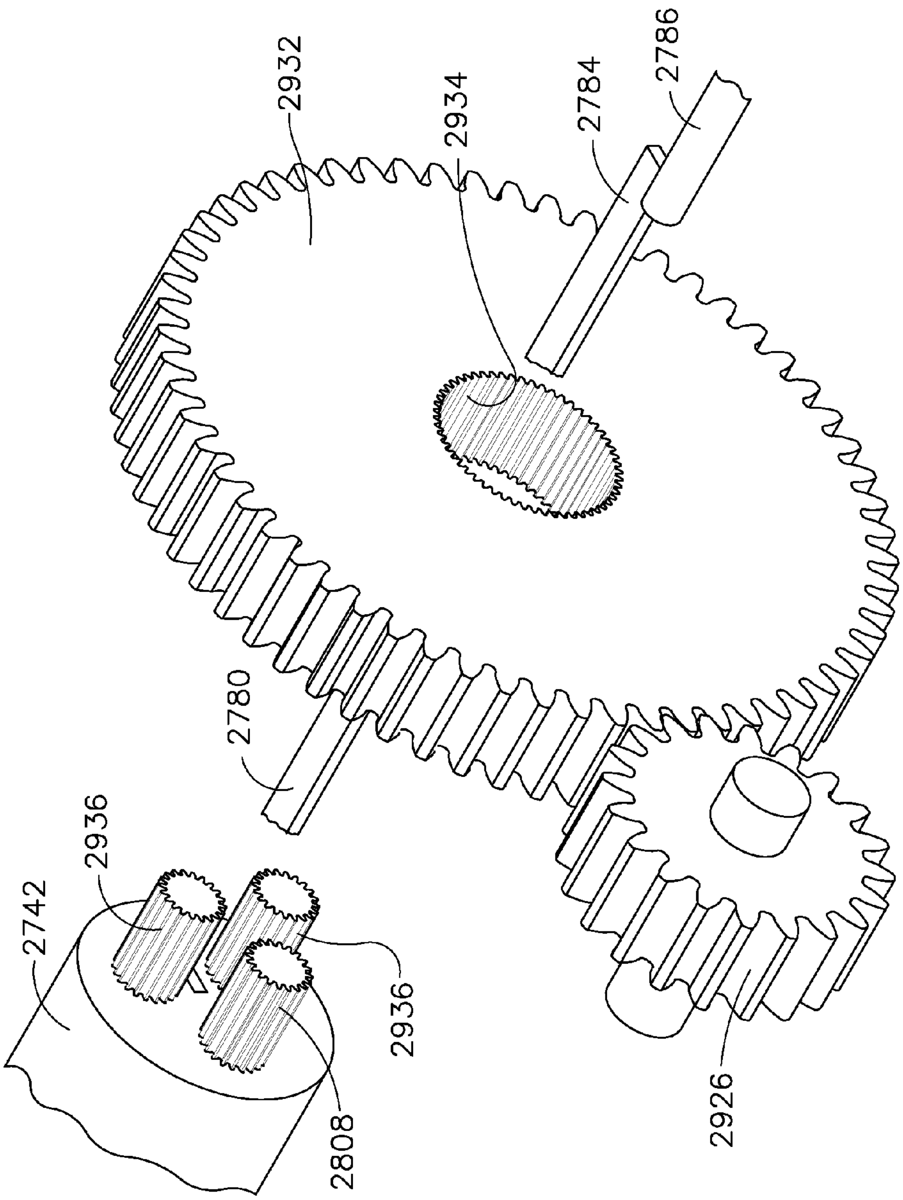


FIG. 61A

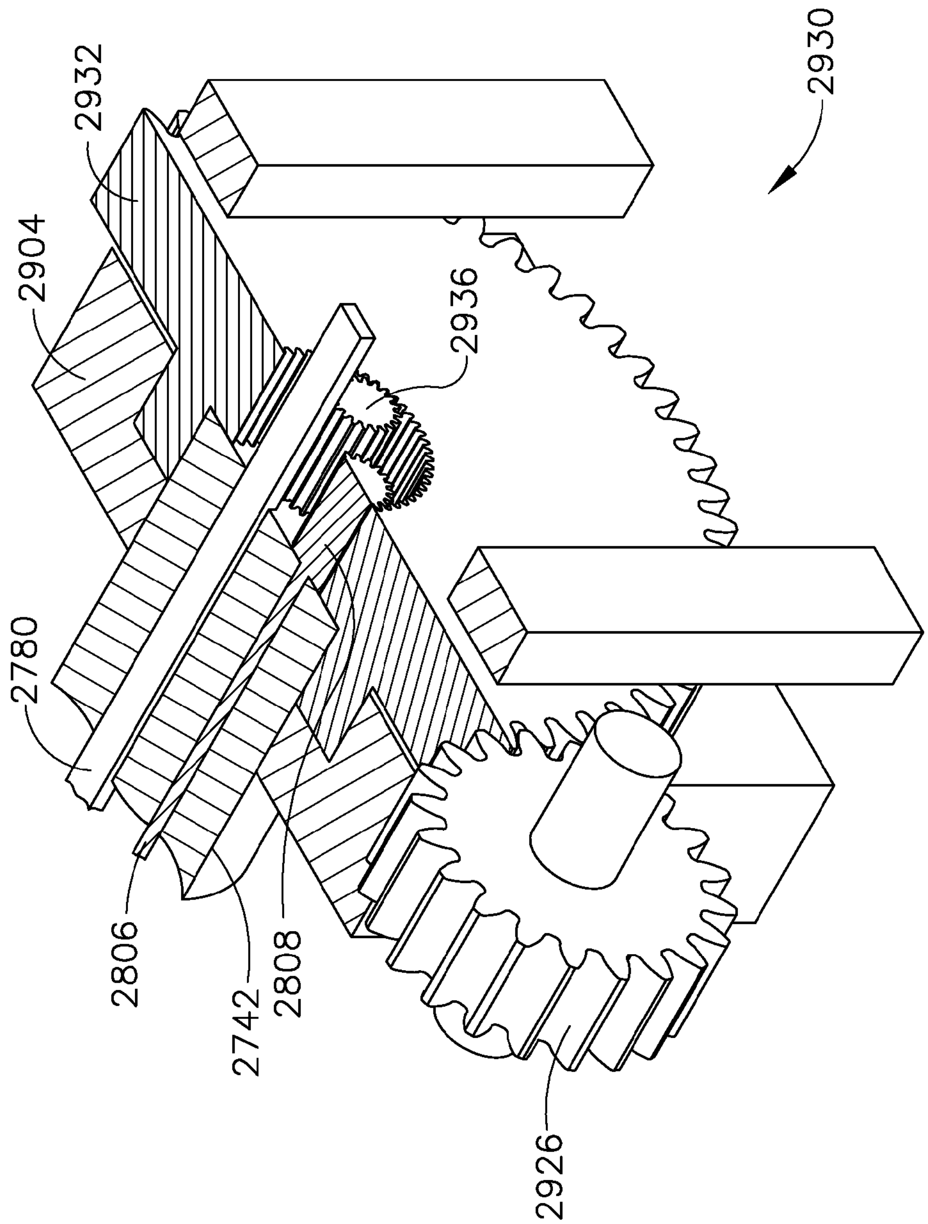


FIG. 61B

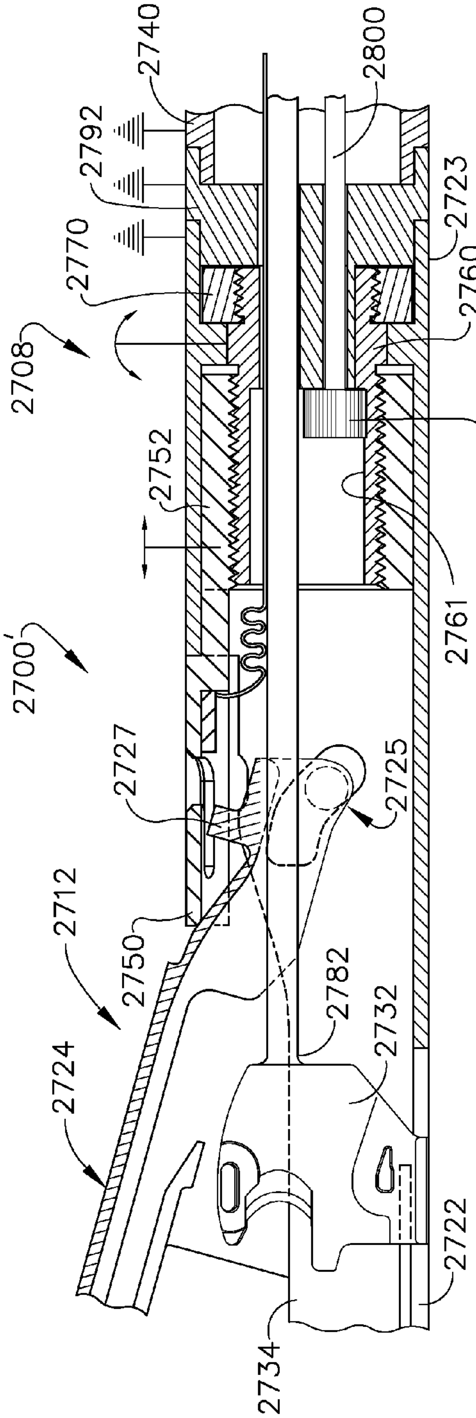
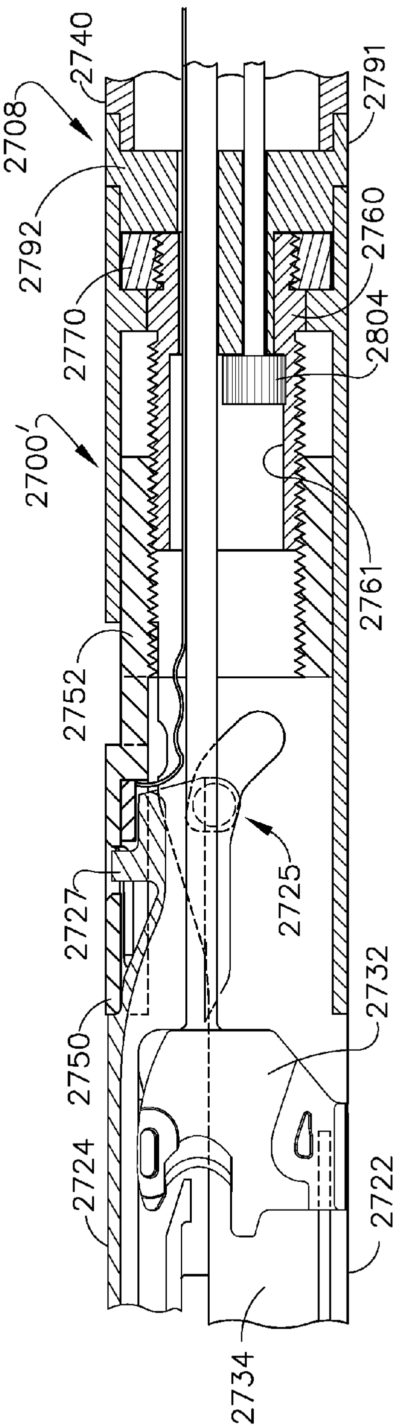

2740
2792
2770
2708
2752
2700'
2727
2712
2750
2724
2800
2723
2760
2804
2761
2725
2782
2732
2722
2734

FIG. 62


2740
2708
2792
2770
2700'
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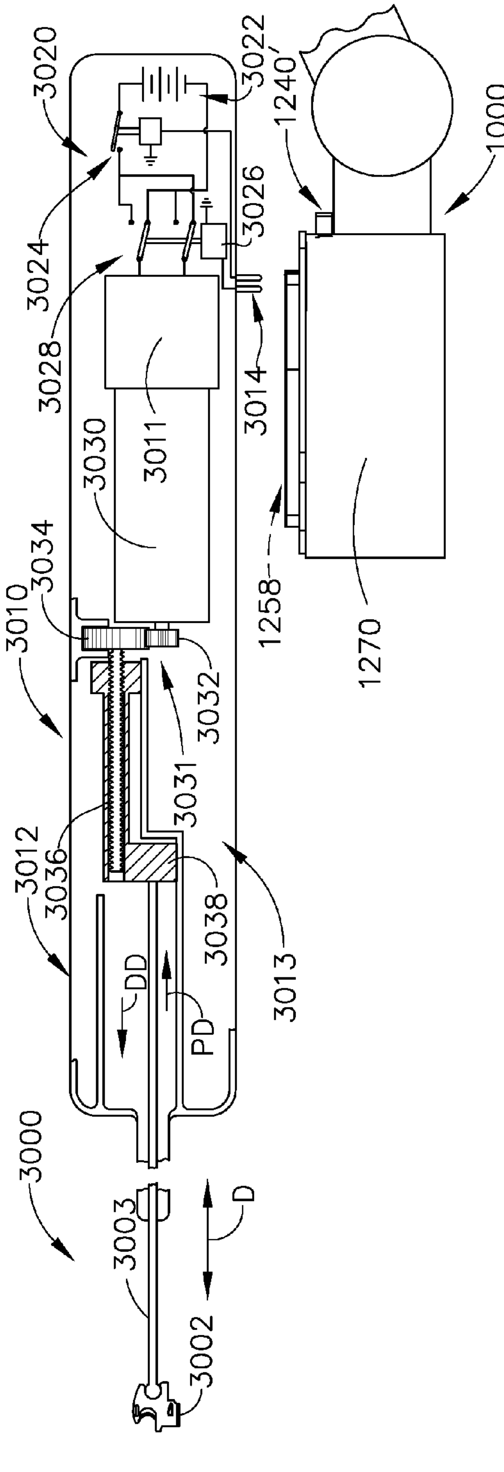
2727
2750
2724
2791
2760
2804
2761
2725
2732
2722
2734

FIG. 63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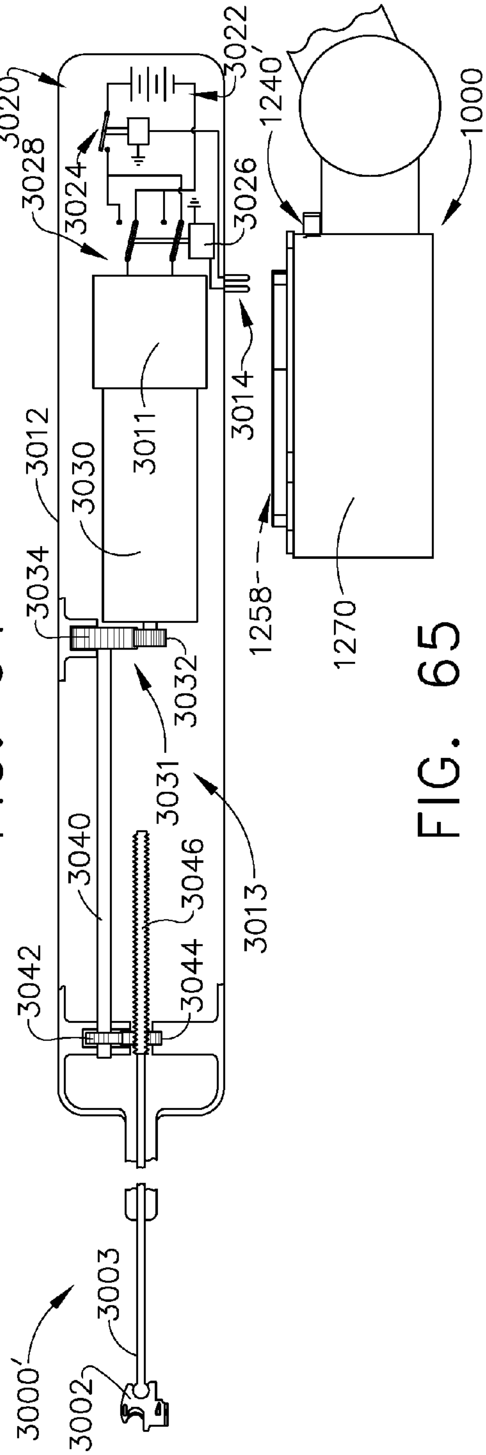
1240'
1000
3024
3026
3028
3014
3011
3030
3034
3010
1258
1270
3032
3031
3012
3036
3038
3013
DD
PD
3000
D
3003
3002

FIG. 64


3020
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1240'
1000
3028
3024
3026
3014
3012
3030
3011
3034
1258
1270
3032
3031
3040
3046
3013
3042
3044
3003
3000'
3002

FIG. 65

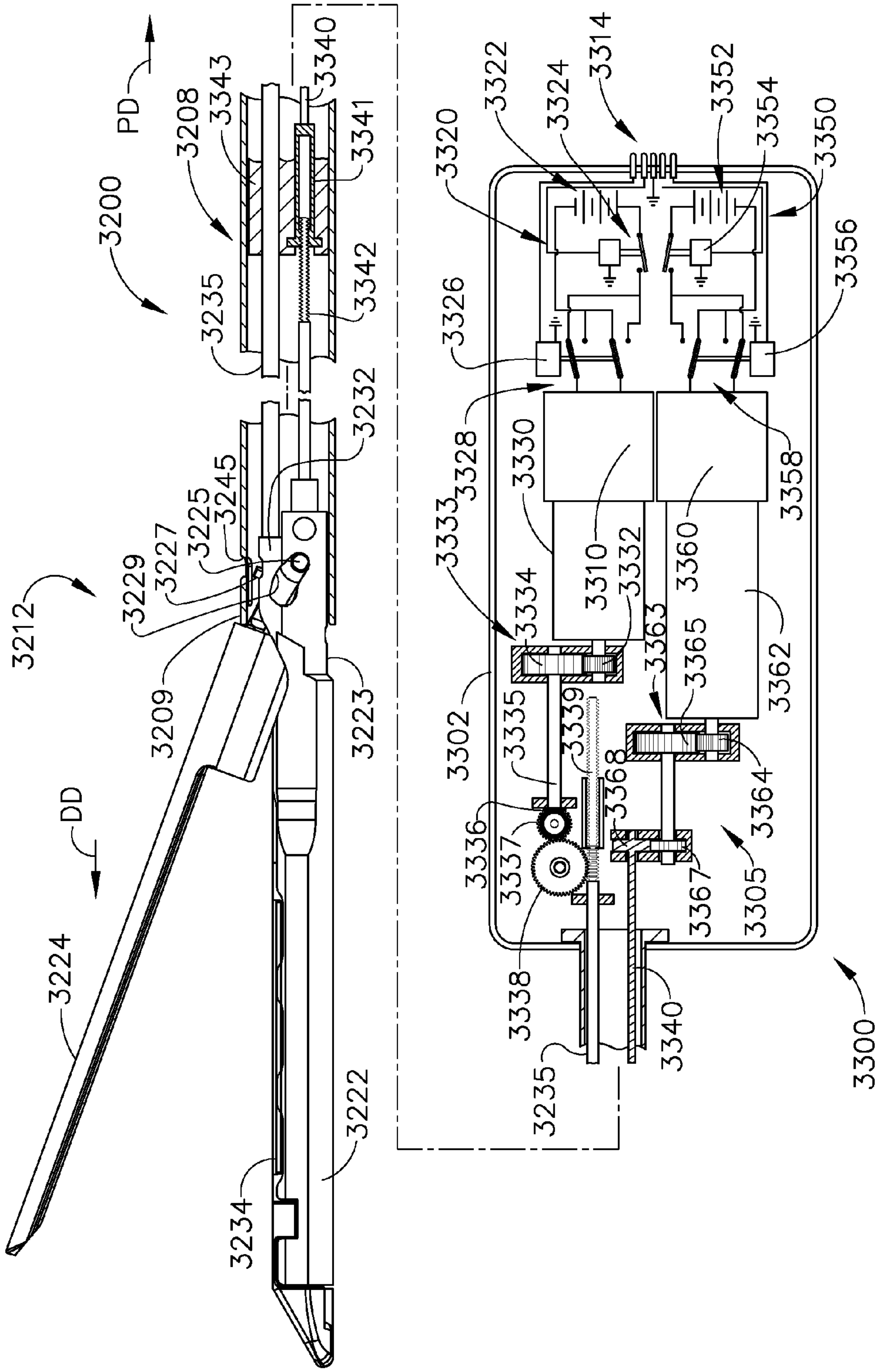

3200
3208
3343
3340
3341
3342
3235
3232
3245
3225
3227
3229
3212
3209
3223
PD
DD
3224
3222
3234
3314
3322
3324
3352
3354
3350
3320
3356
3326
3328
3330
3358
3333
3334
3310
3332
3360
3363
3365
3362
3302
3335
3339
3368
3336
3337
3338
3364
3367
3305
3340
3235
3300

FIG. 66

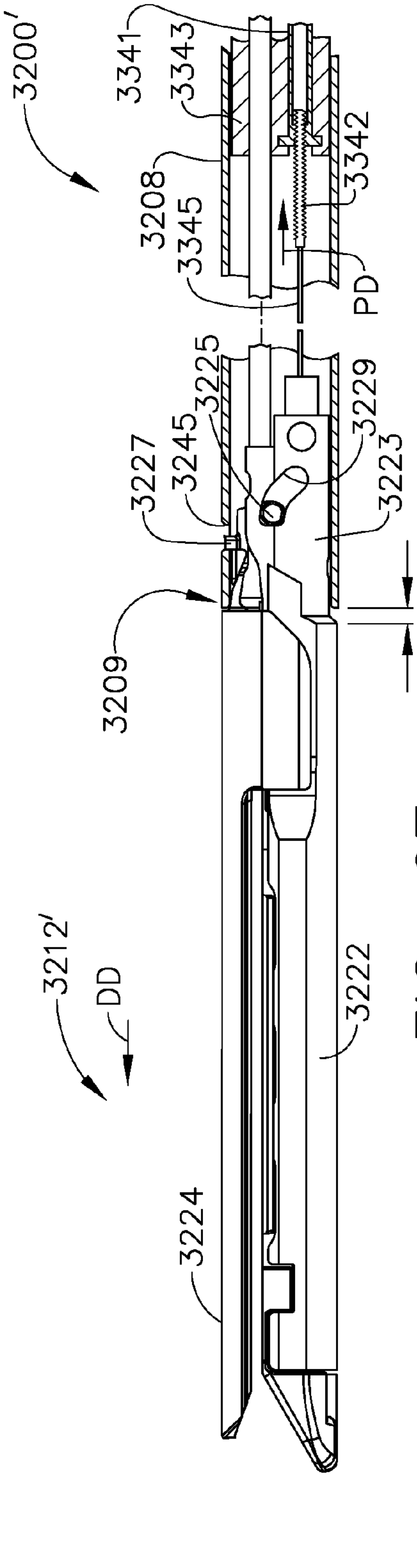

3200′
3341
3343
3208
3342
3345
PD
3225
3229
3245
3227
3223
3209
3212′
DD
3222
3224

FIG. 67

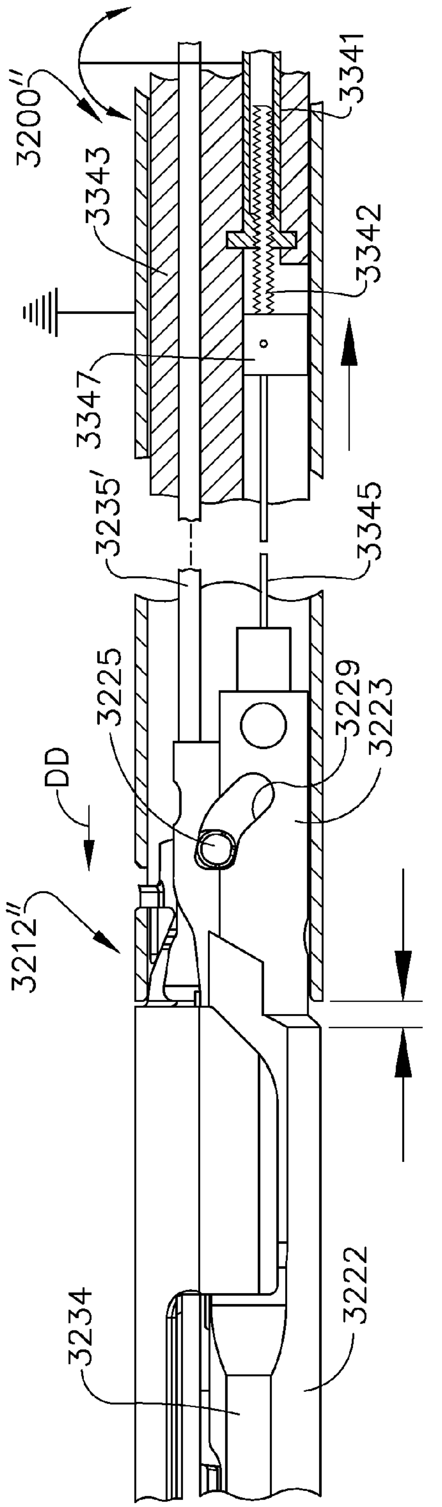

3200″
3341
3343
3342
3347
3235′
3345
3225
3229
3223
DD
3212″
3222
3234

FIG. 68

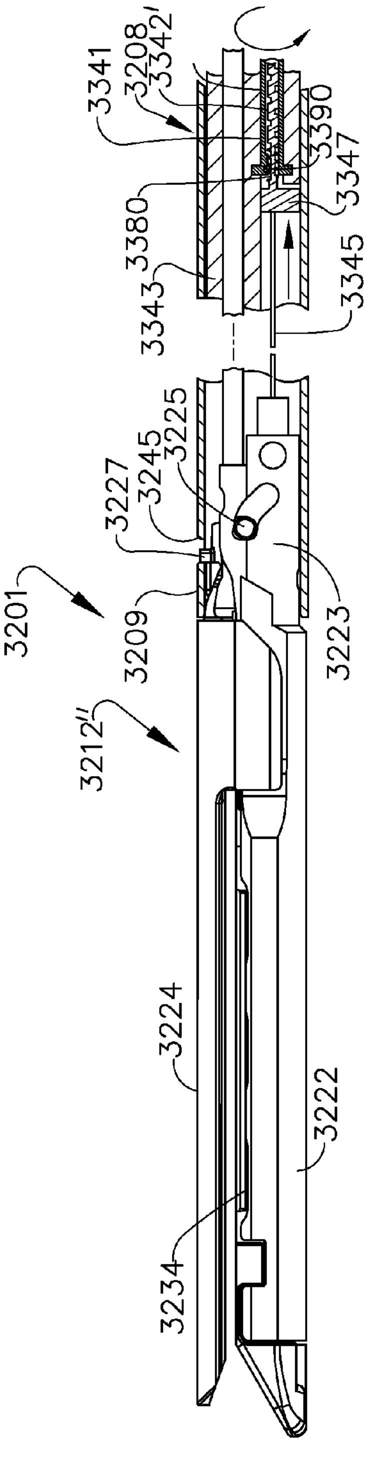


FIG. 69

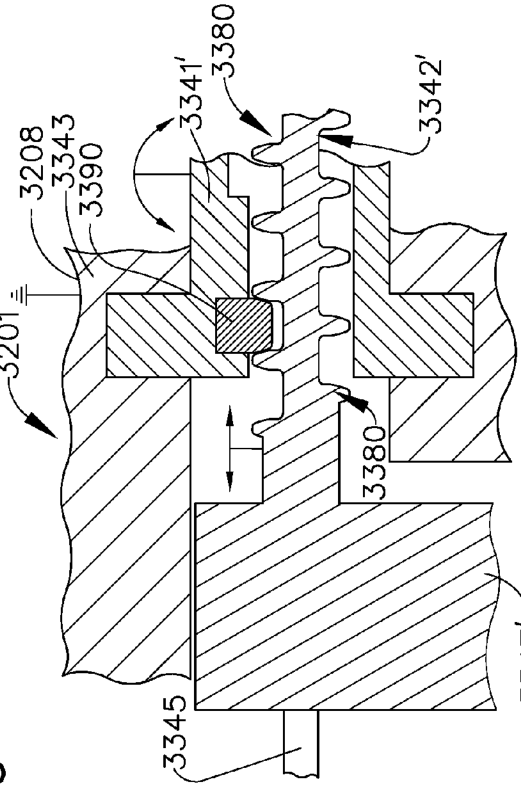


FIG. 71

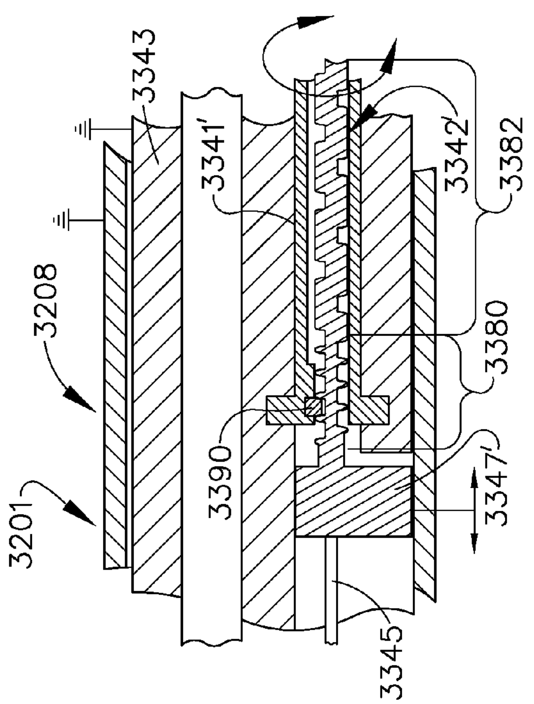
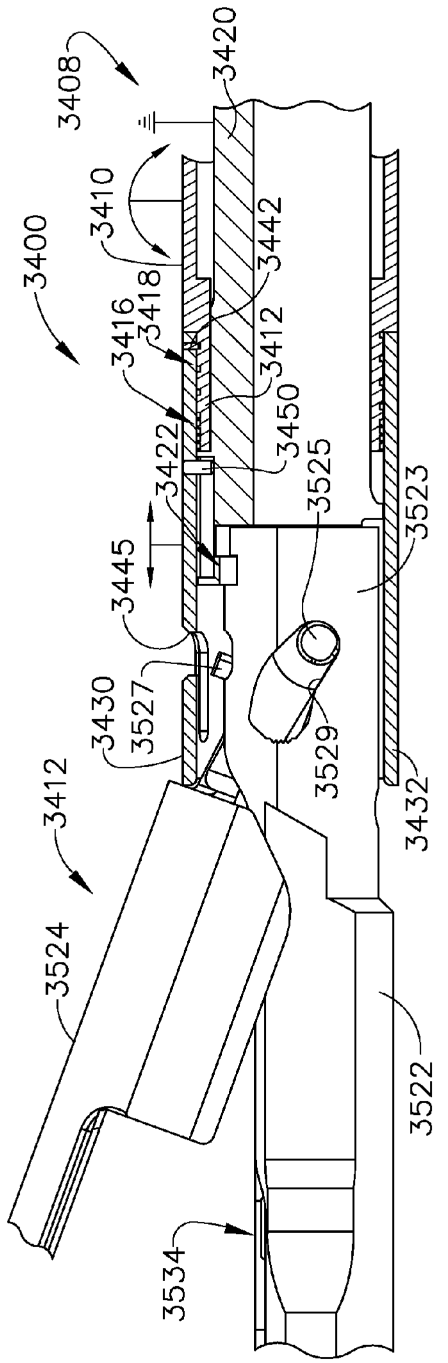
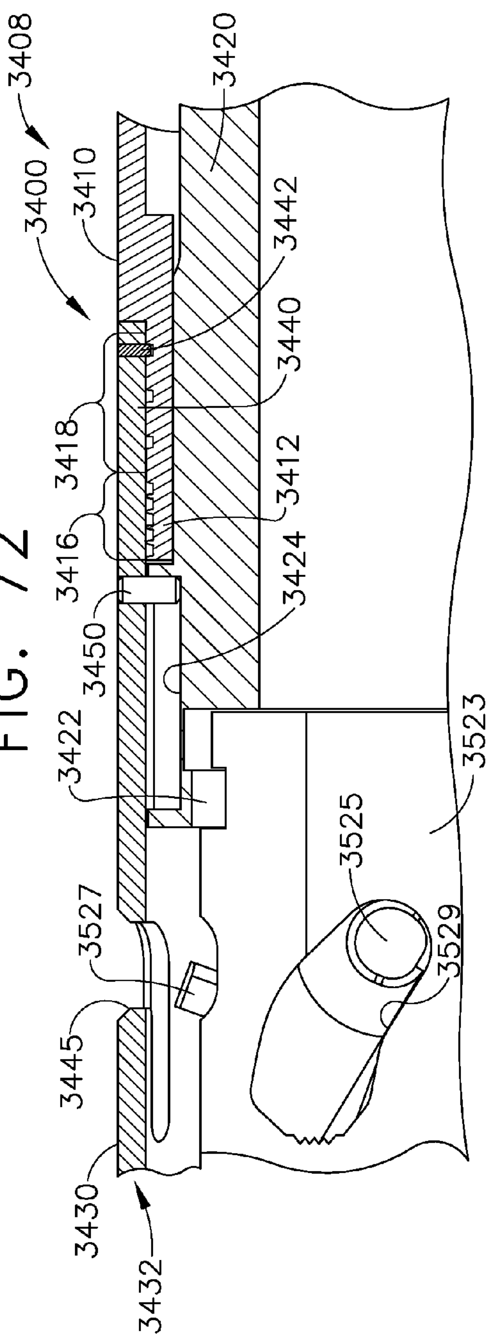


FIG. 70



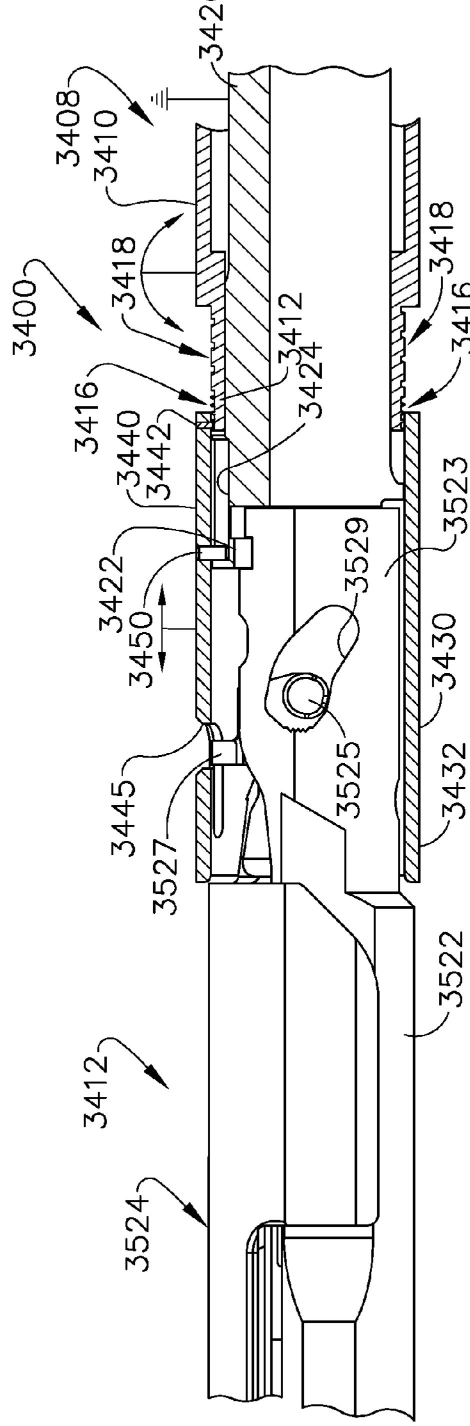
3408
3420
3410
3400
3442
3416
3418
3412
3450
3422
3525
3523
3445
3430
3527
3529
3432
3412
3524
3522
3534

FIG. 72



3408
3420
3400
3410
3442
3440
3418
3412
3416
3424
3450
3422
3523
3525
3529
3527
3445
3430
3432

FIG. 73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3408
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3418
3400
3412
3424
3416
3440
3442
3523
3529
3422
3450
3430
3525
3445
3432
3527
3522
3524

FIG. 74

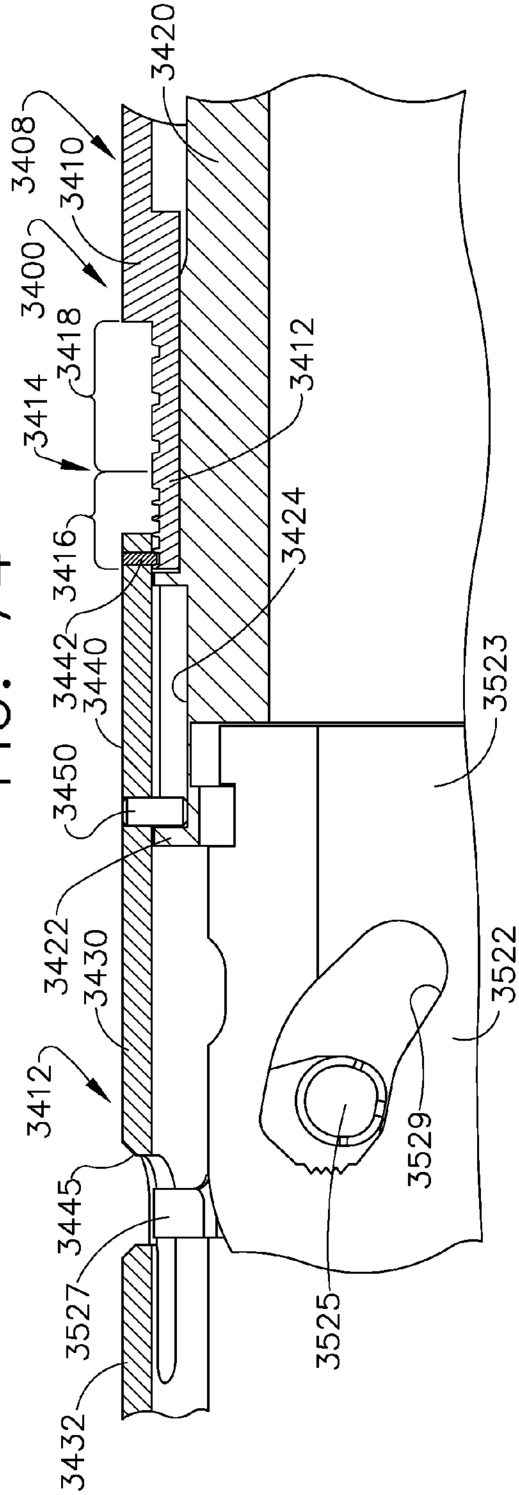
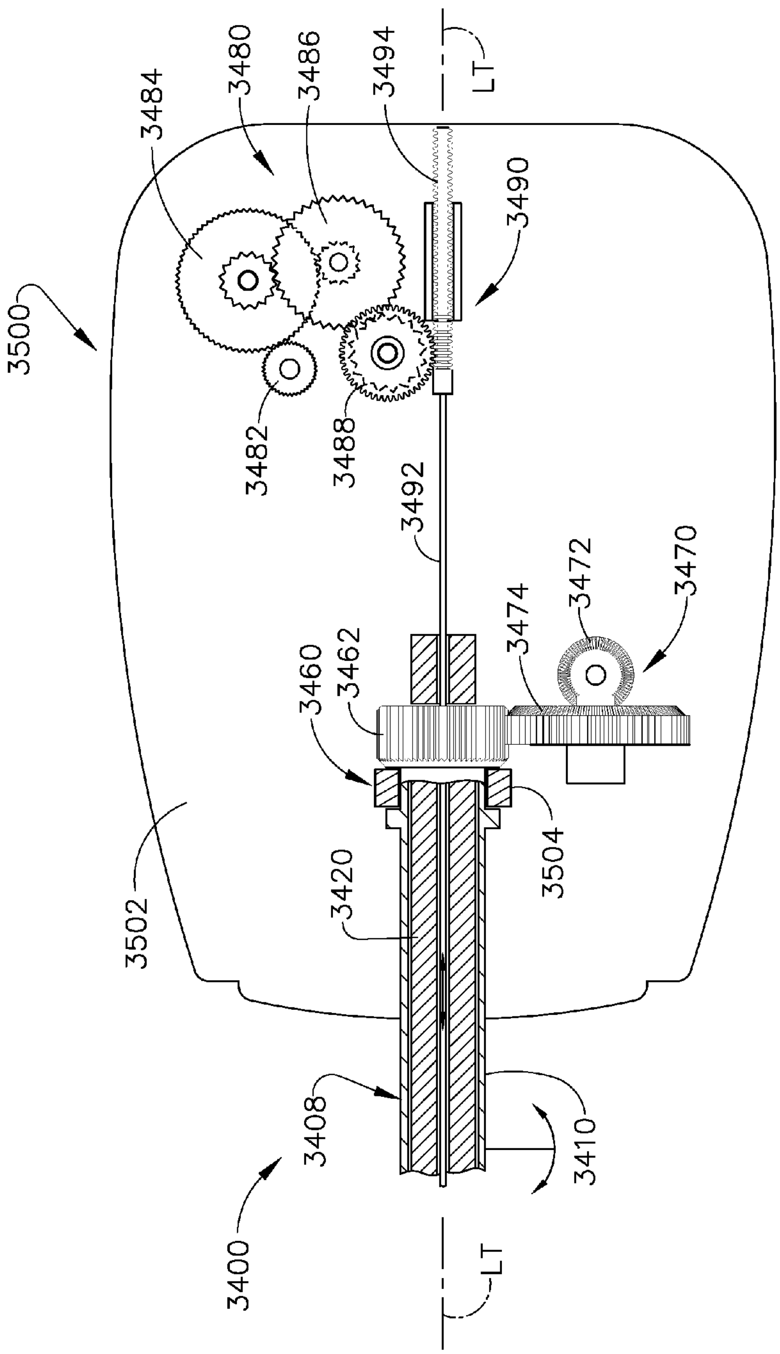

3420
3408
3410
3400
3418
3414
3412
3416
3424
3442
3440
3523
3450
3422
3430
3522
3412
3529
3445
3527
3525
3432

FIG. 75



3400
3408
3410
3420
3460
3462
3470
3472
3474
3480
3482
3484
3486
3488
3490
3492
3494
3500
3502
3504
LT
LT

FIG. 76

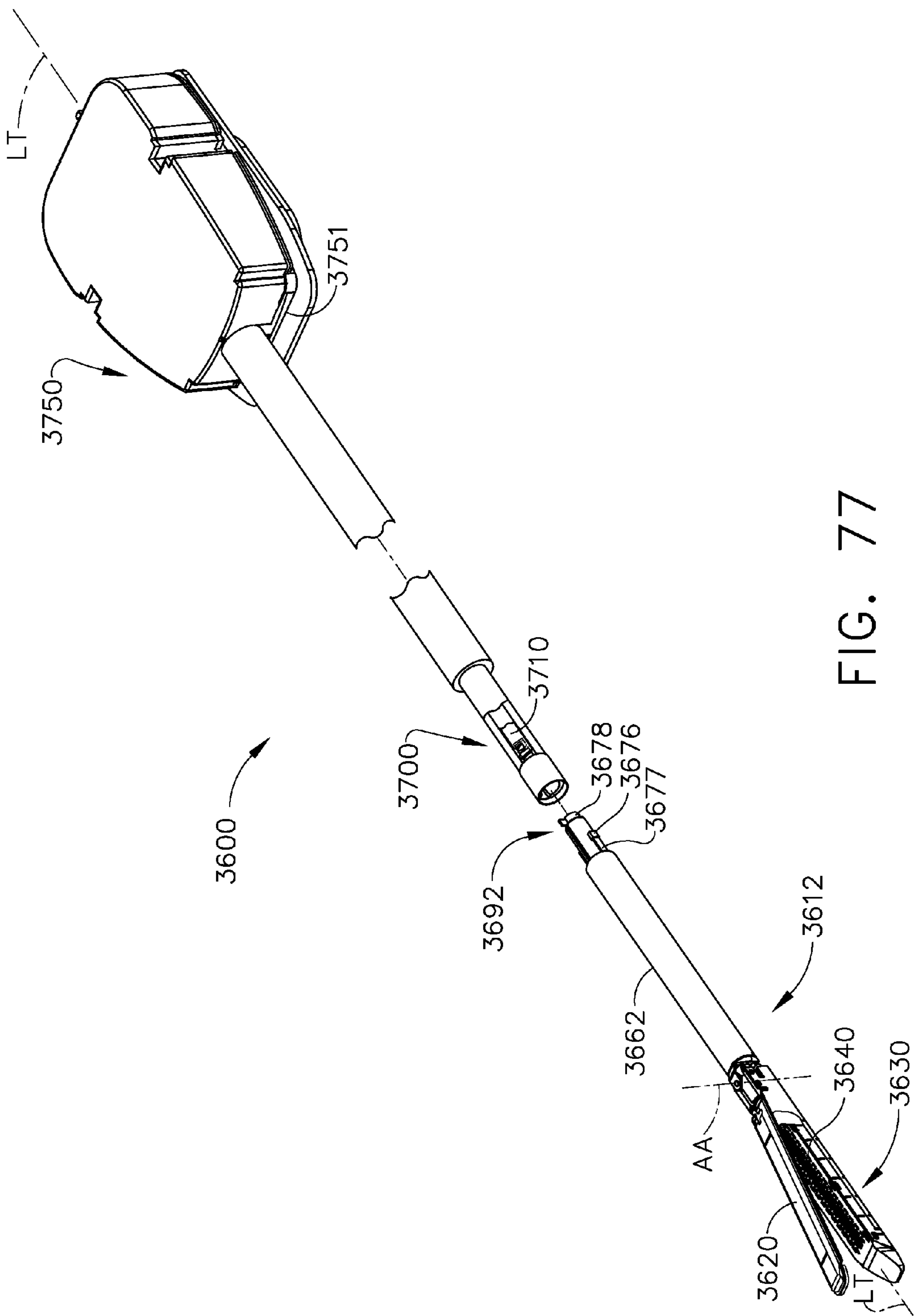

LT
3751
3750
3710
3700
3678
3676
3677
3600
3692
3612
3662
3640
3630
AA
3620
LT

FIG. 77

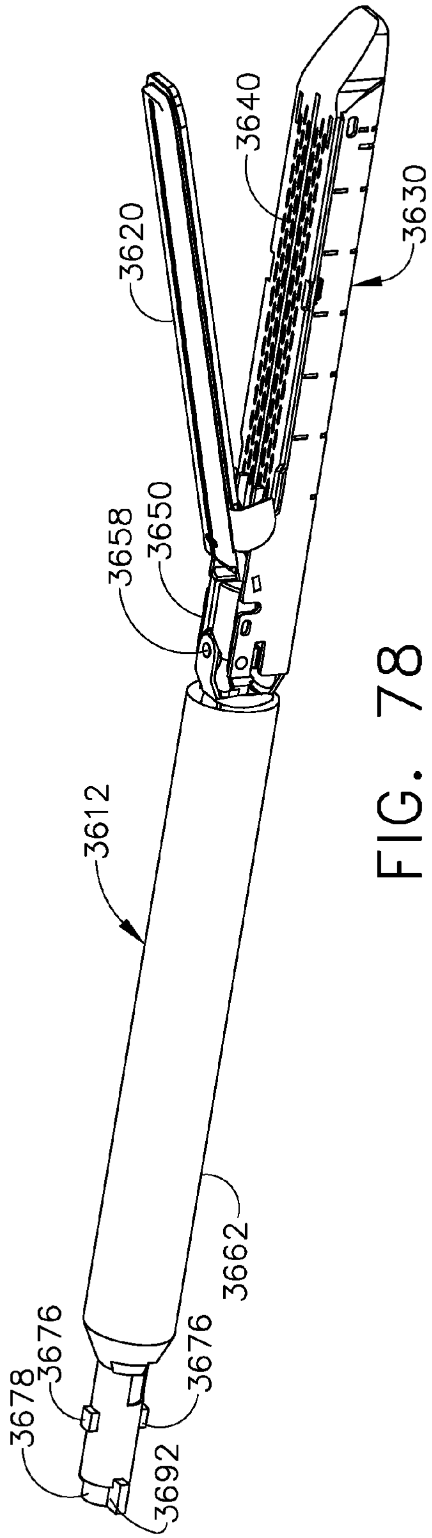

3620
3640
3630
3658
3650
3612
3662
3676
3676
3678
3692

FIG. 78

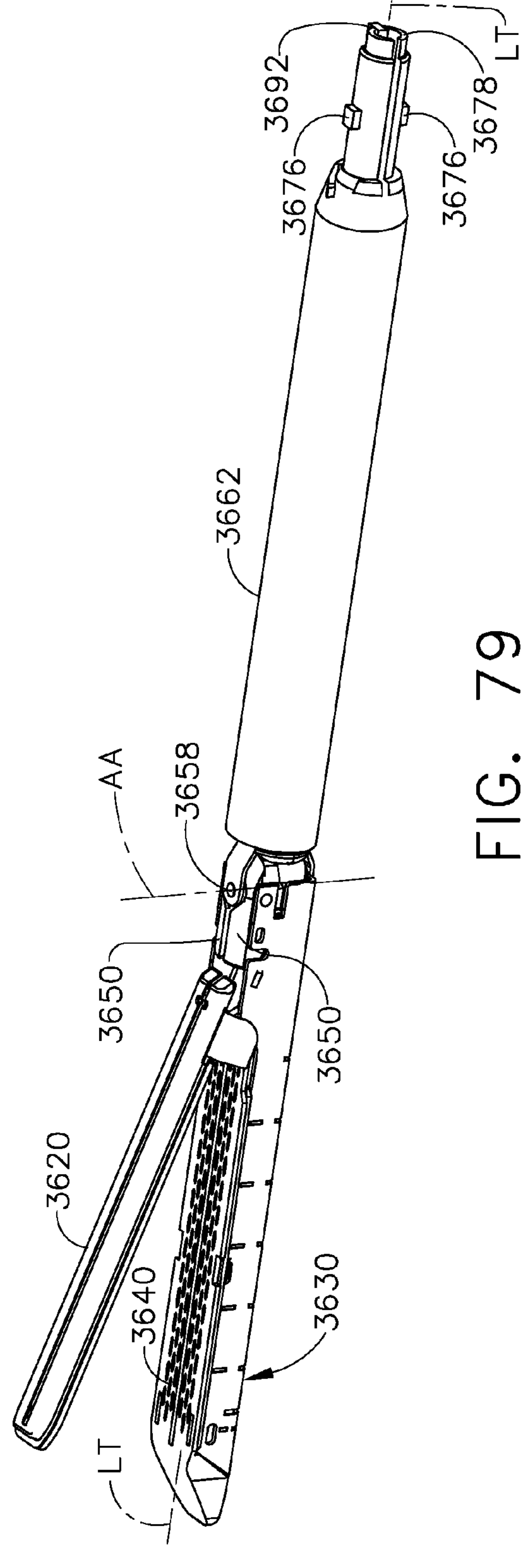

LT
3692
3678
3676
3676
3662
AA
3658
3650
3650
3620
3640
3630
LT

FIG. 79

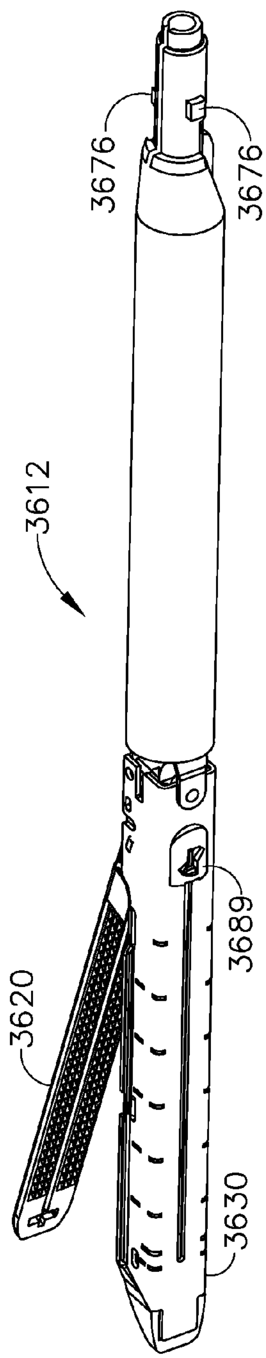

3676
3676
3612
3689
3620
3630

FIG. 80

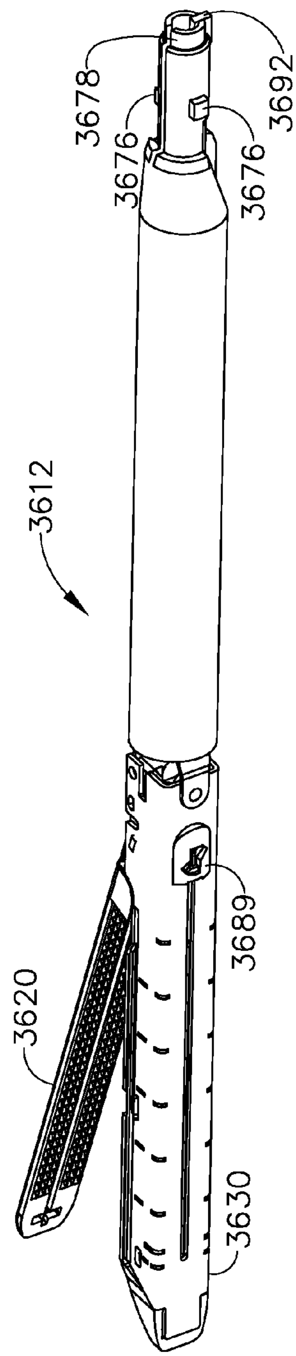
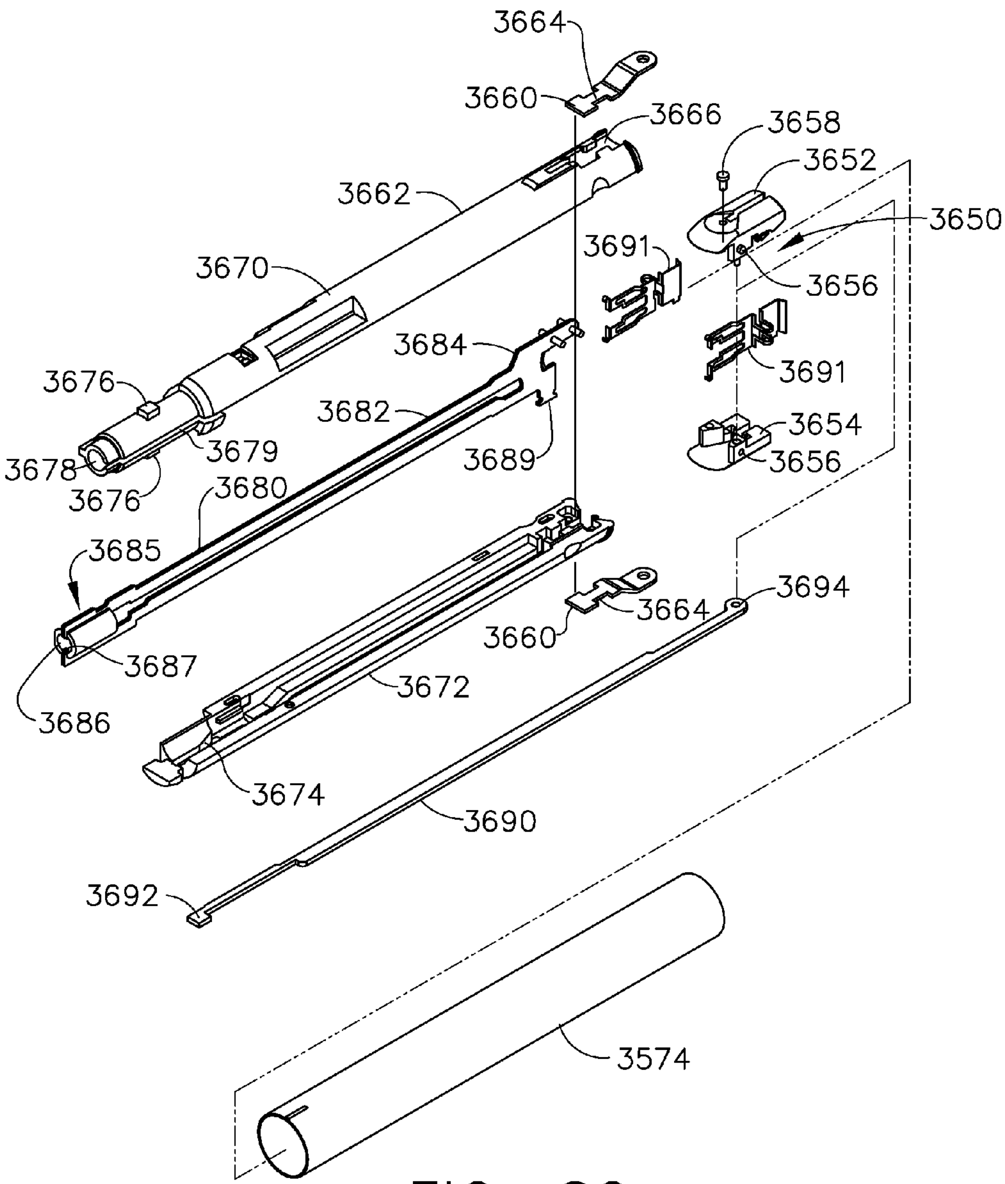

3678
3692
3676
3676
3612
3689
3620
3630

FIG. 81


3664
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3666
3658
3652
3662
3650
3691
3670
3656
3684
3691
3676
3682
3654
3679
3689
3656
3678
3676
3680
3685
3694
3664
3660
3687
3672
3686
3674
3690
3692
3574

FIG. 82

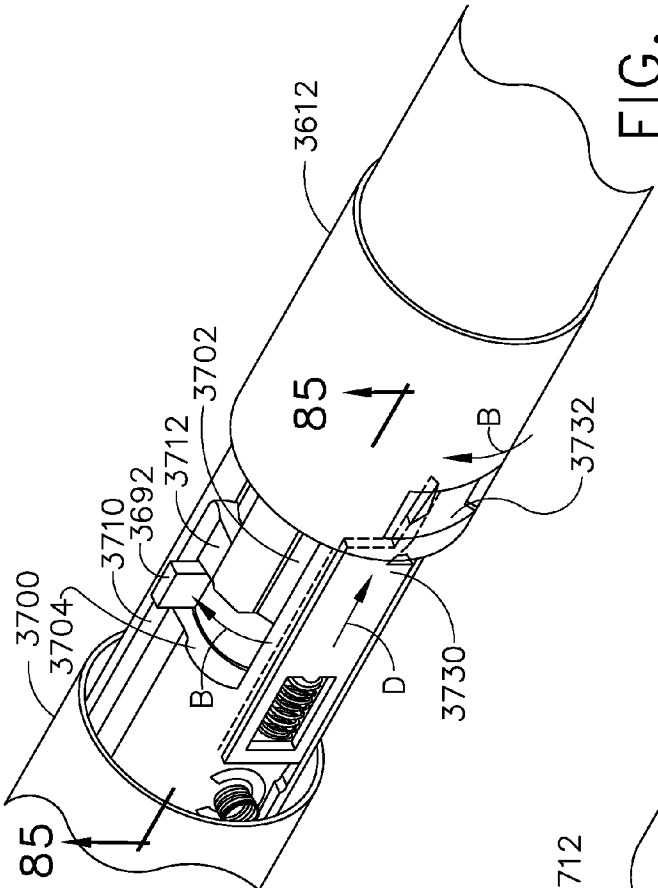

3612
3702
3712
3692
3710
3700
3704
85
B
3732
D
3730
85

FIG. 83

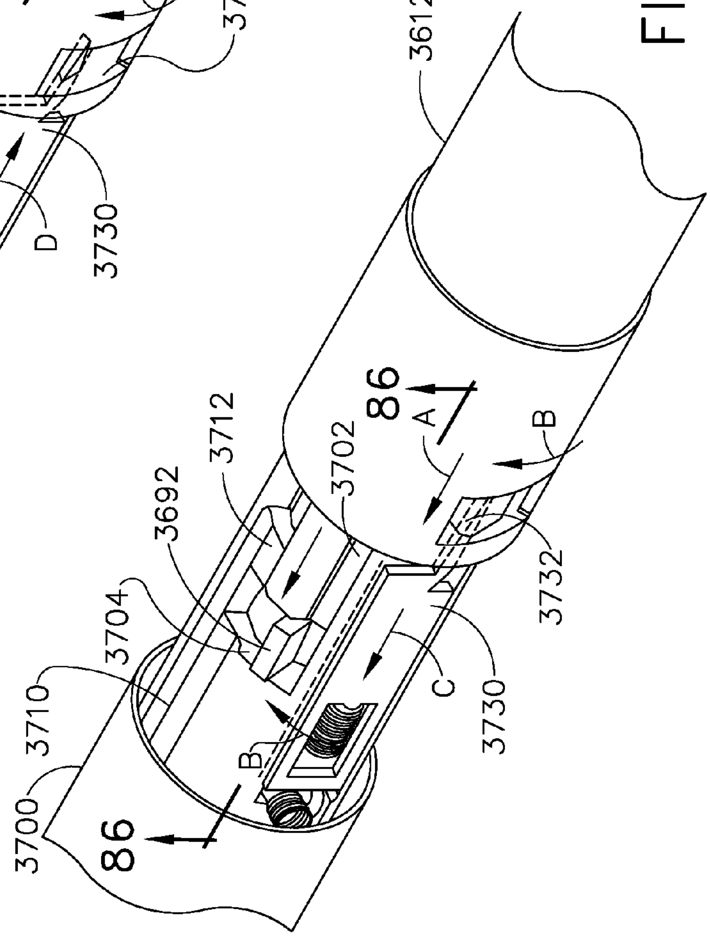

3612
86
A
B
3712
3702
3692
3704
3710
3700
3732
C
3730
B
86

FIG. 84

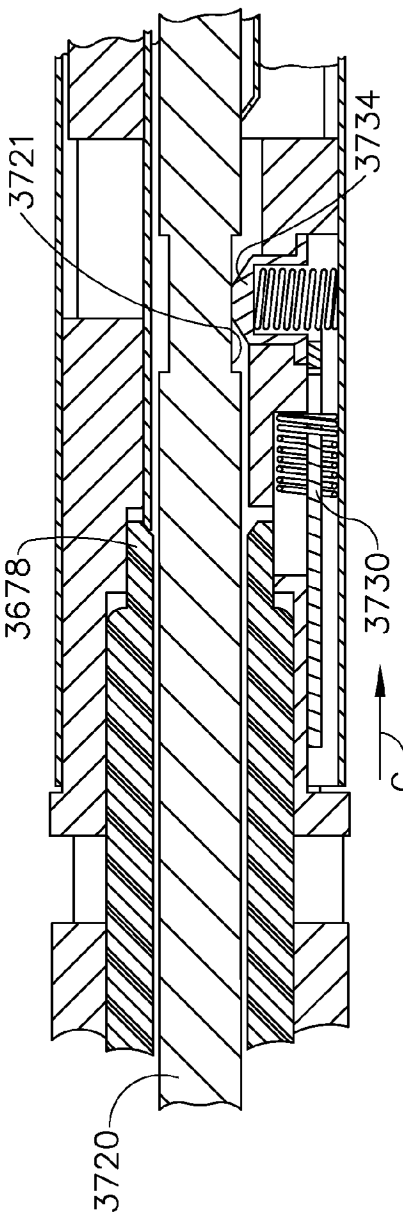

3721
3734
3678
3730
C
3720

FIG. 85

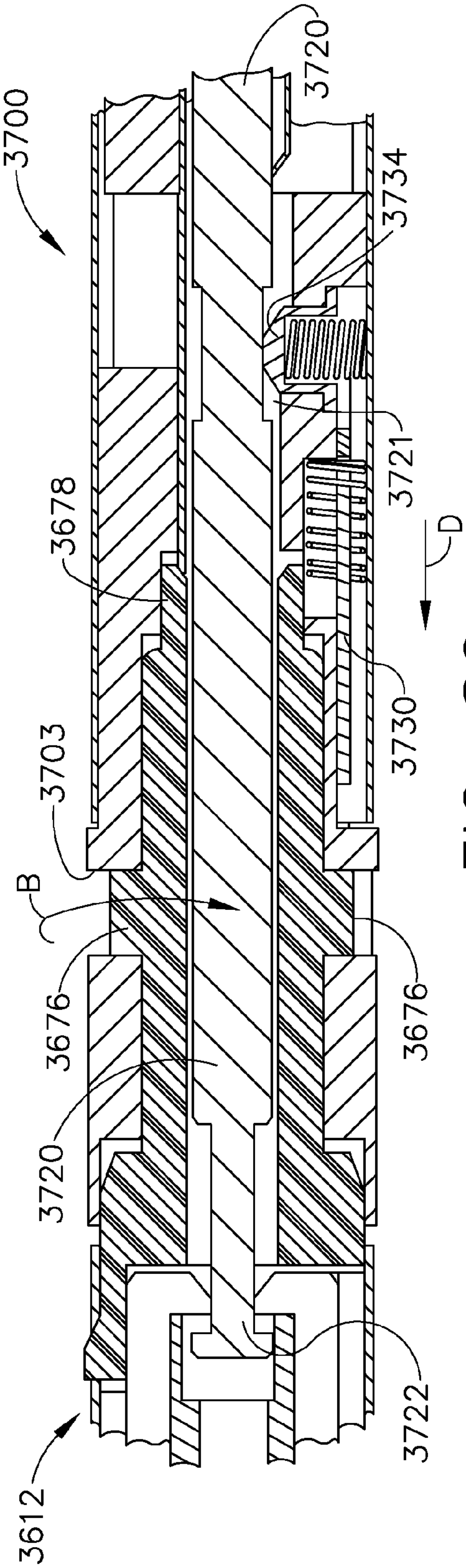

3720
3700
3734
3721
3678
D
3730
3703
B
3676
3676
3720
3722
3612

FIG. 86

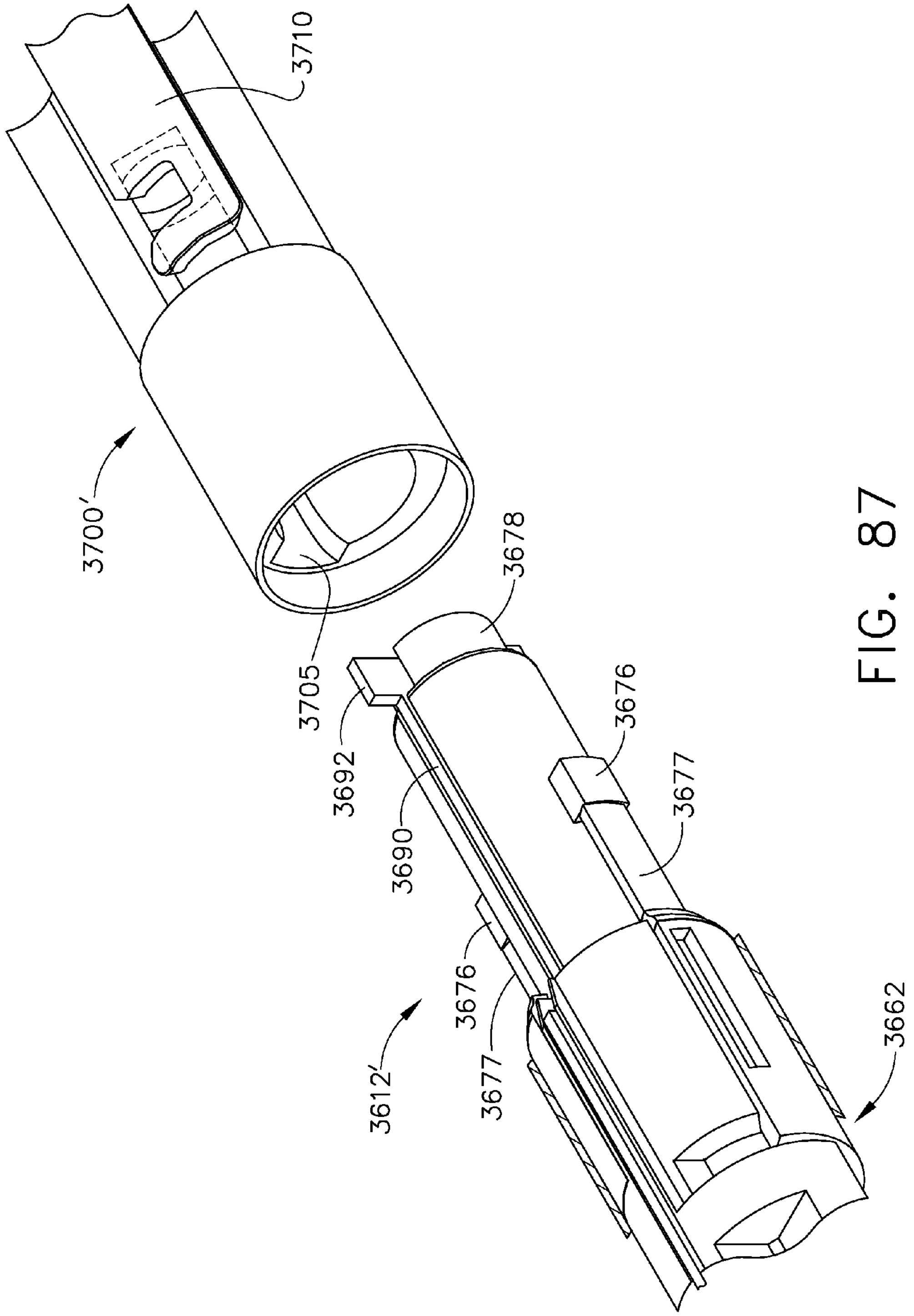


FIG. 87

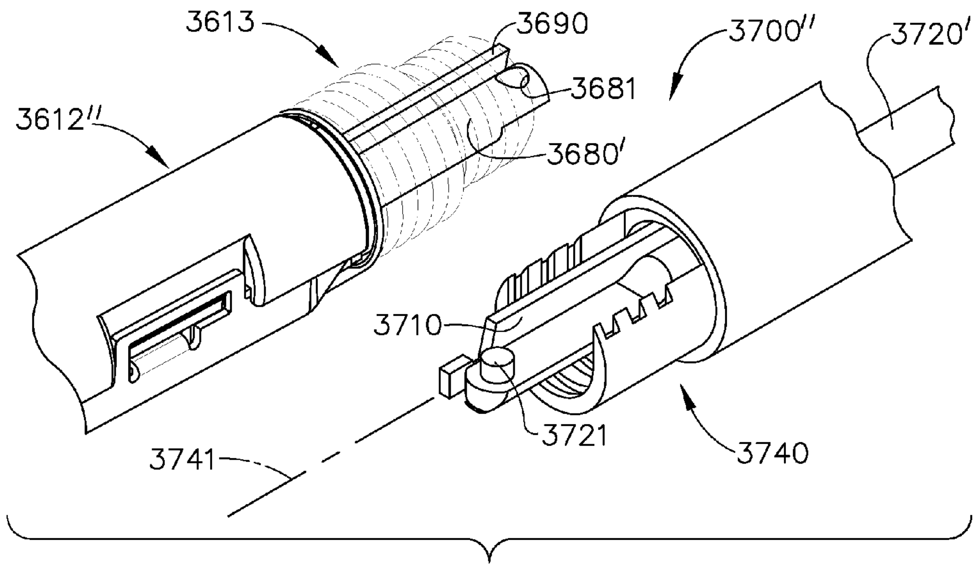

3613
3690
3681
3612''
3680'
3700''
3720'
3710
3721
3741
3740

FIG. 88

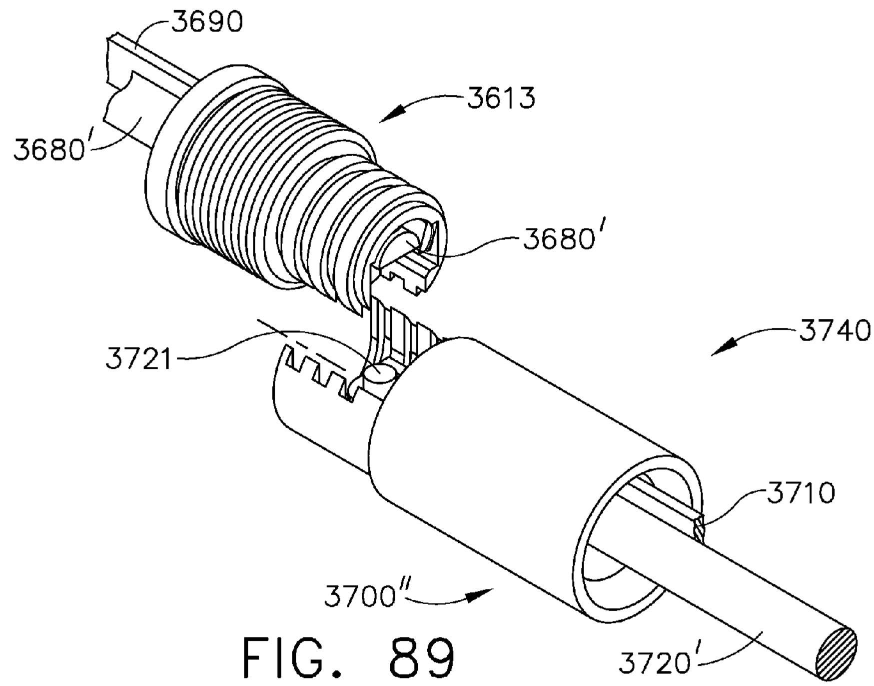

3690
3613
3680'
3680'
3721
3740
3710
3700''
3720'

FIG. 89

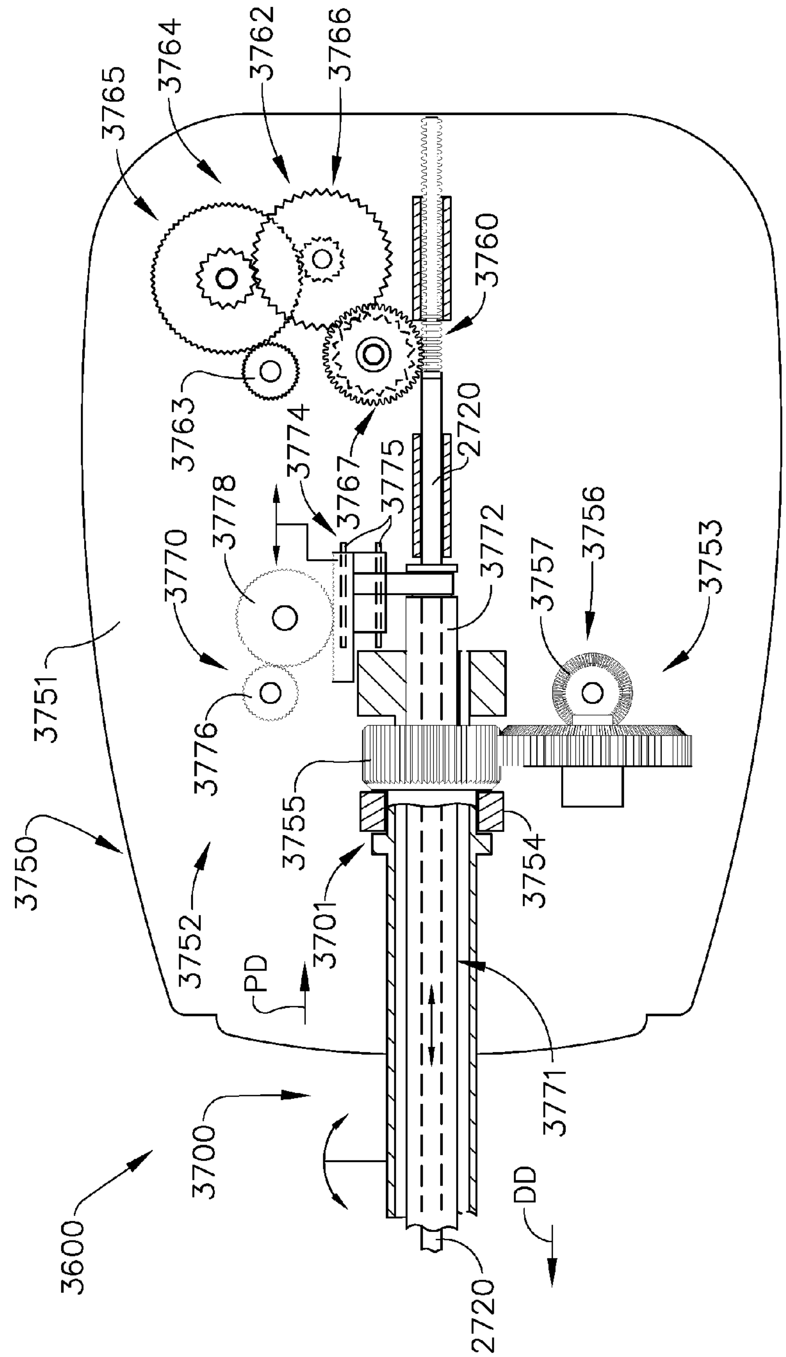
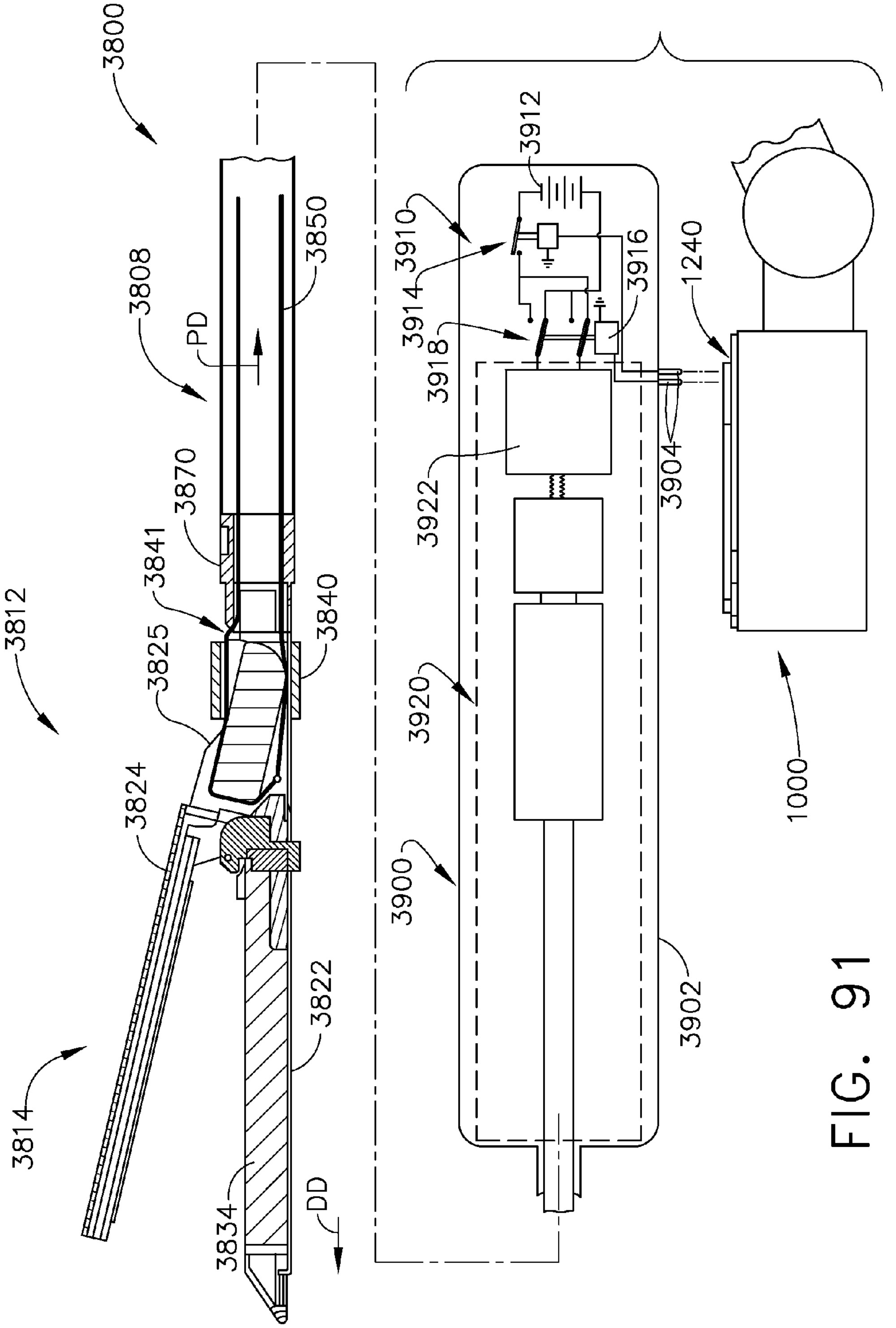

3765
3764
3762
3766
3760
3763
3774
3767
2720
3775
3778
3770
3772
3756
3757
3753
3751
3776
3755
3750
3752
3754
3701
PD
3771
3700
3600
DD
2720

FIG. 90


3800
3808
PD
3850
3870
3841
3840
3825
3812
3824
3822
3814
3834
DD
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3910
3914
3916
1240
3918
3904
3922
3920
3900
3902
1000

FIG. 91

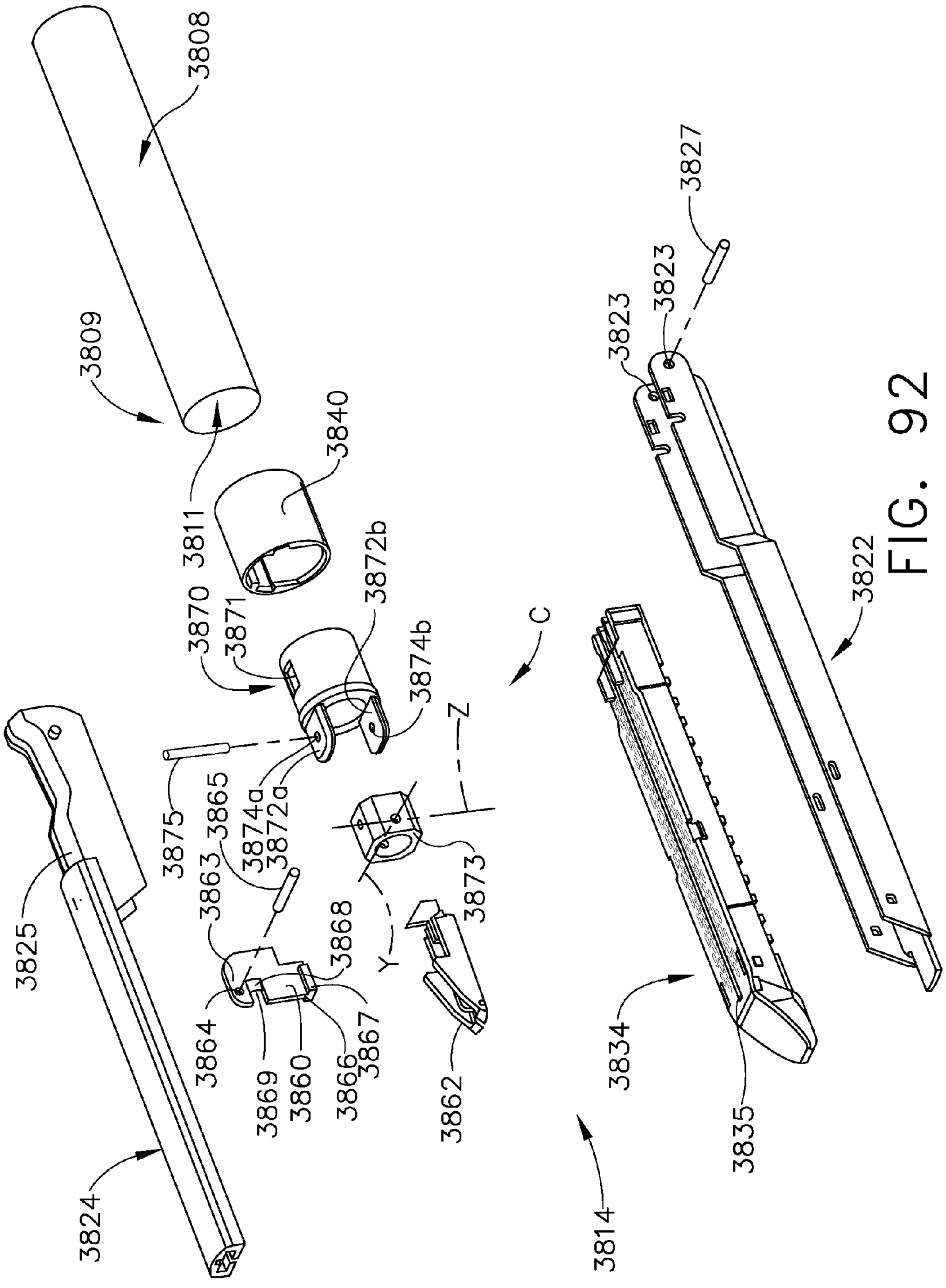

3808
3809
3811
3840
3870
3871
3872b
3874b
C
Z
3875
3874a
3872a
3865
3863
3868
3873
Y
3825
3864
3869
3860
3866
3867
3862
3827
3823
3823
3822
3834
3835
3824
3814

FIG. 92

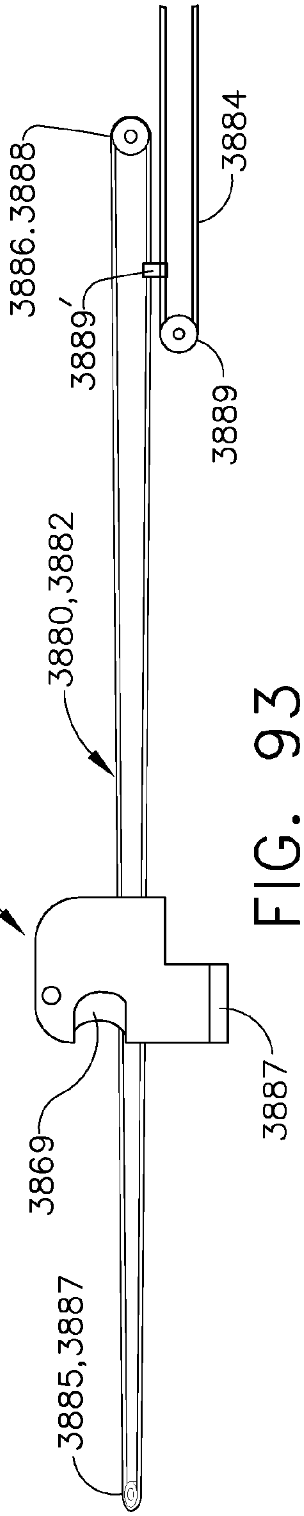

3886,3888
3884
3889'
3889
3880,3882
3860
3869
3887
3885,3887

FIG. 93

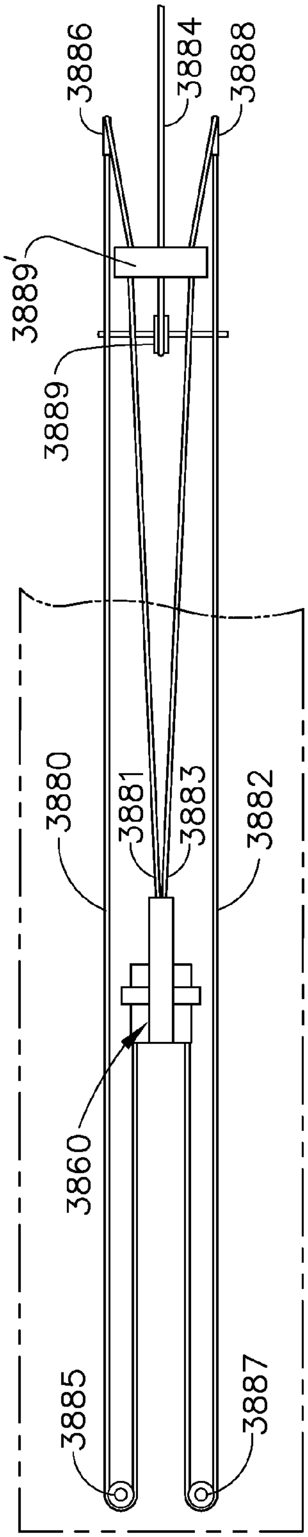

3886
3884
3888
3889'
3889
3880
3881
3883
3882
3860
3885
3887

FIG. 94

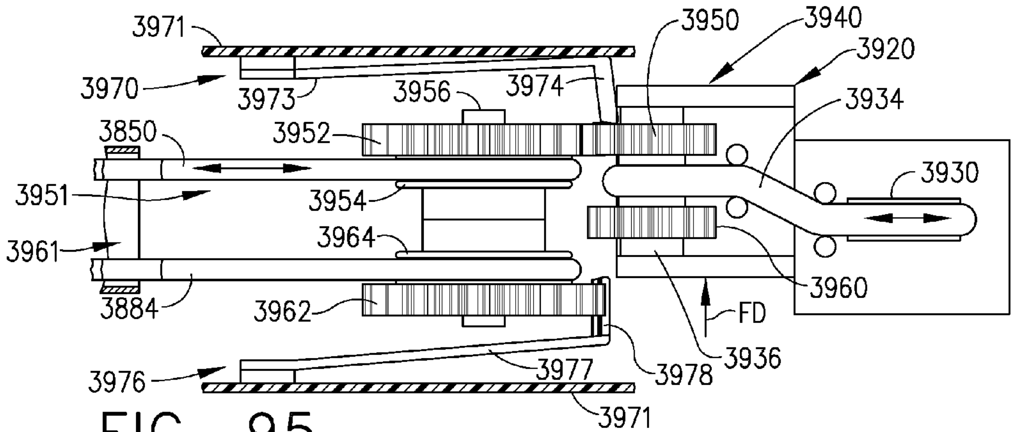


FIG. 95

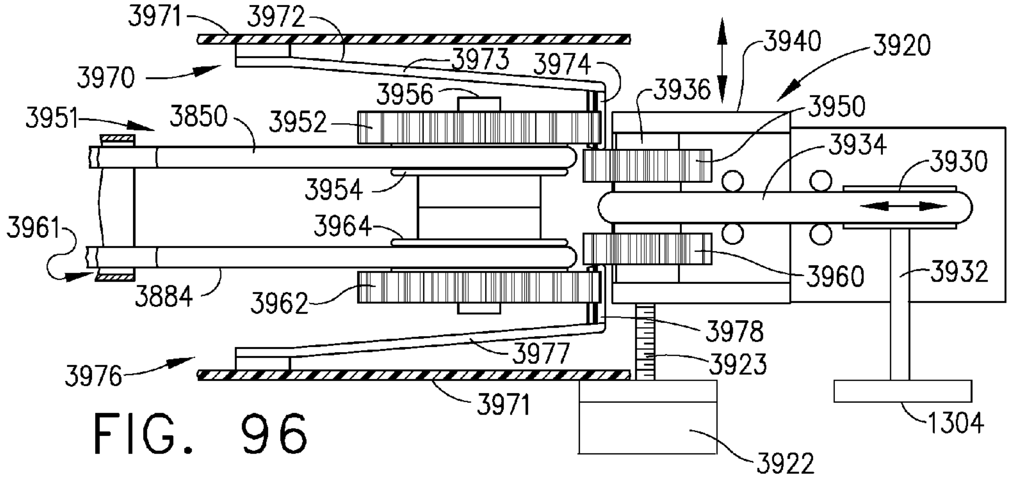


FIG. 96

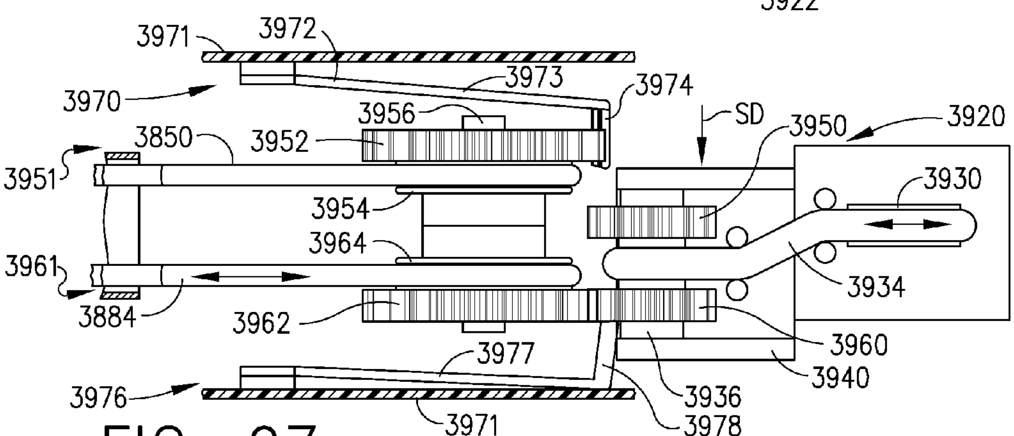


FIG. 97

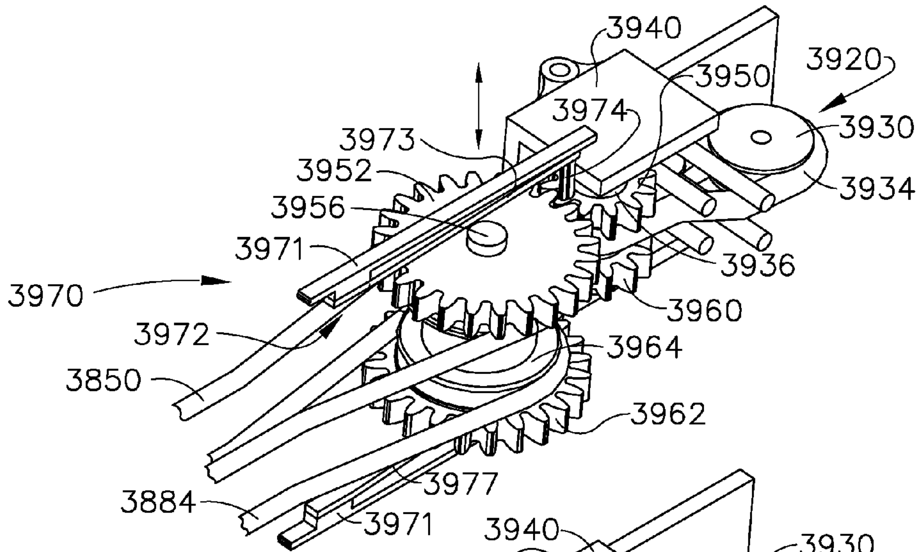


FIG. 98

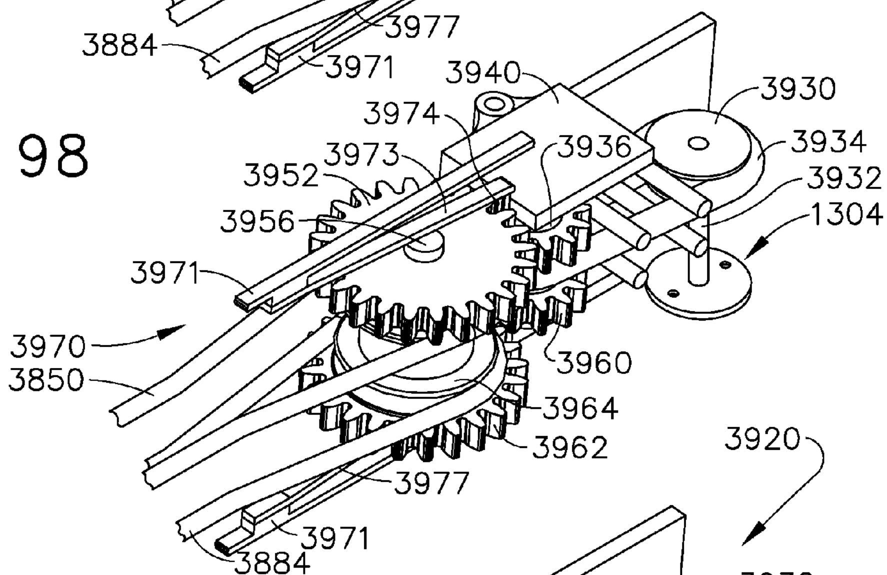


FIG. 99

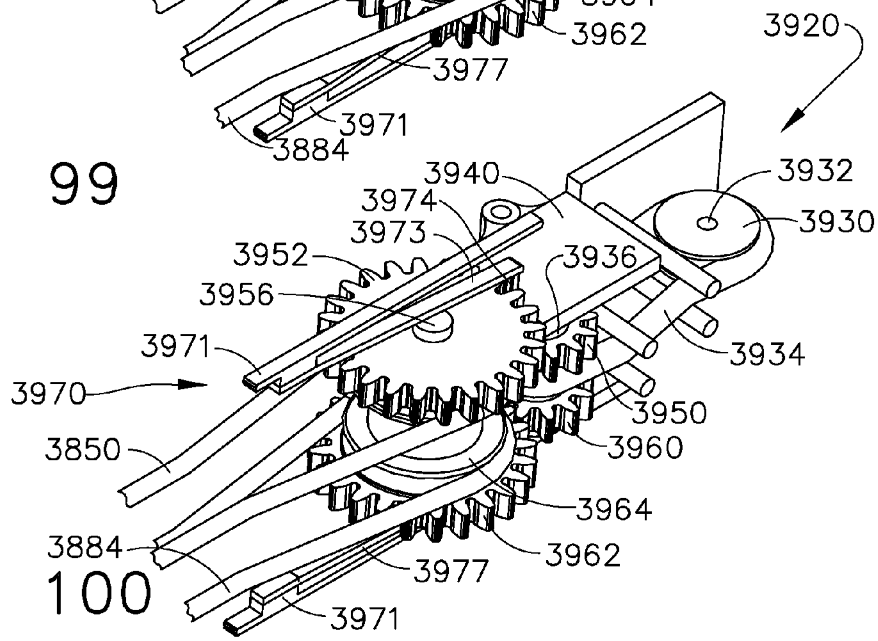


FIG. 100

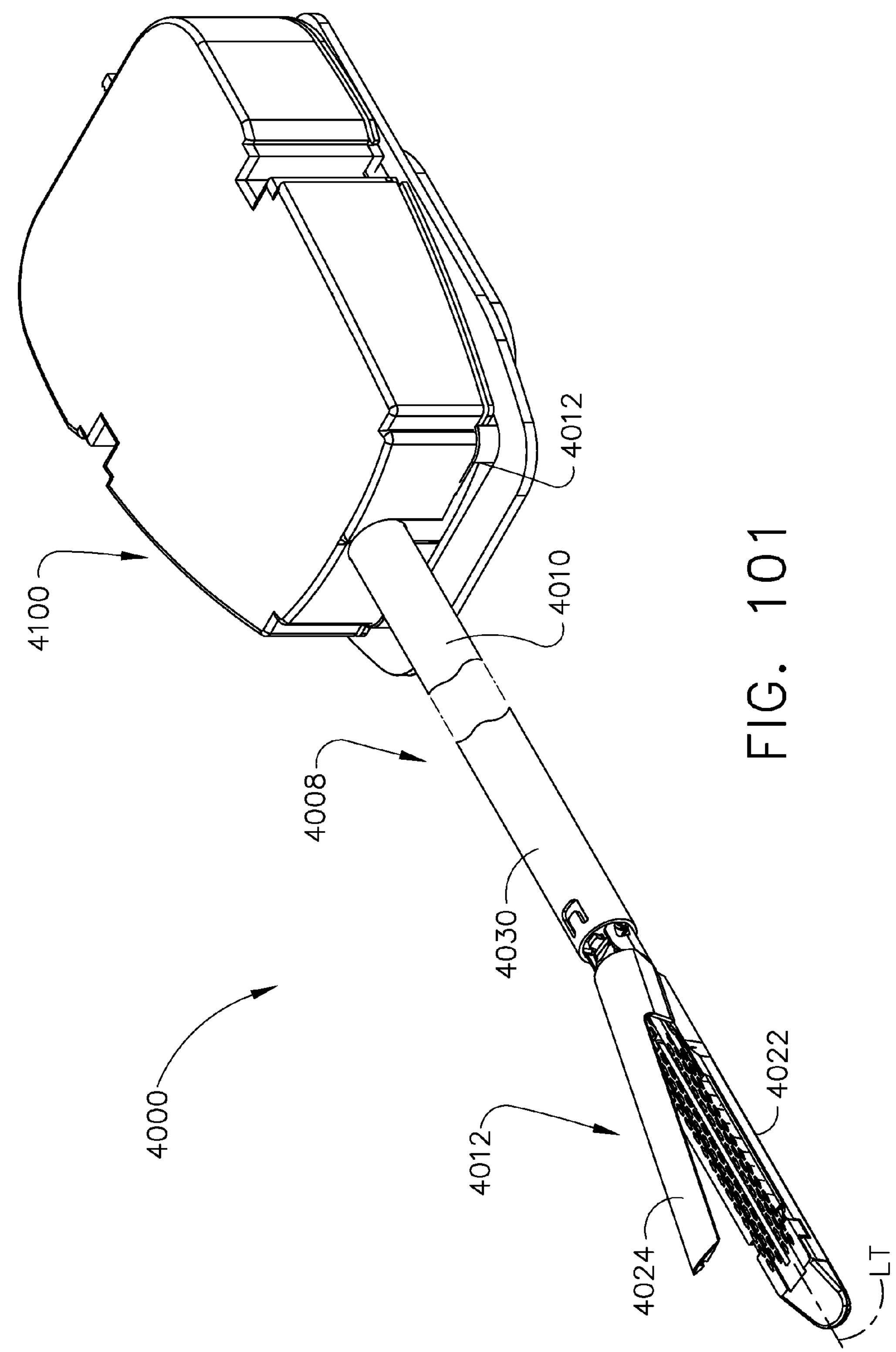


FIG. 101

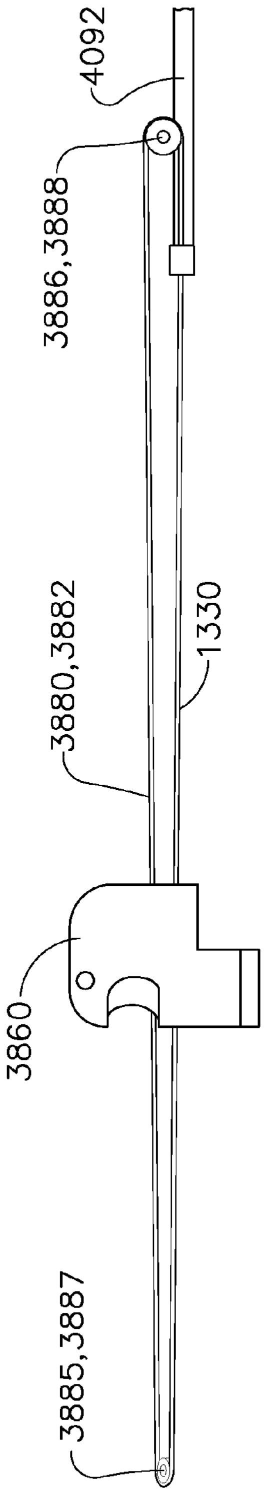


FIG. 102

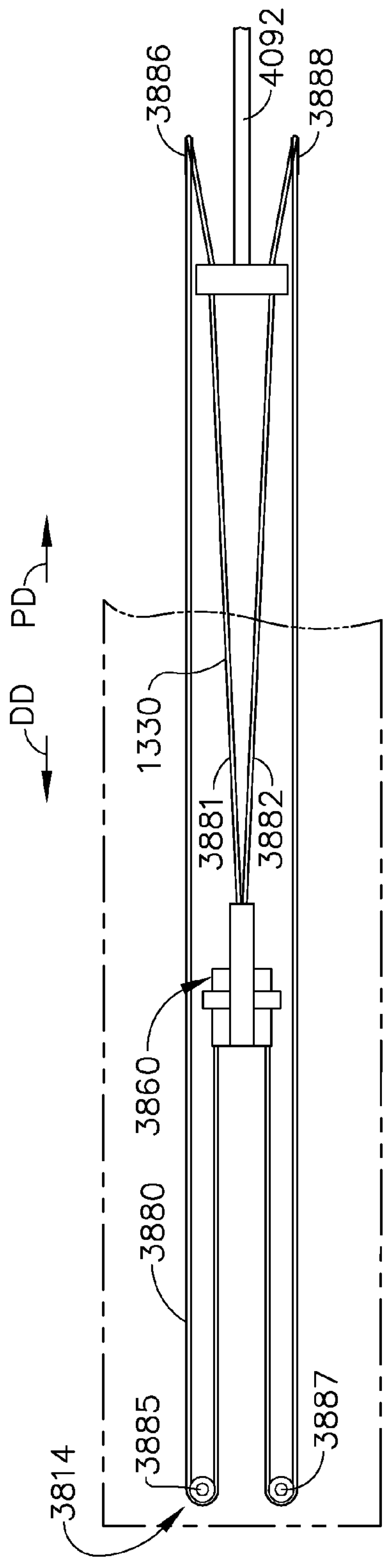
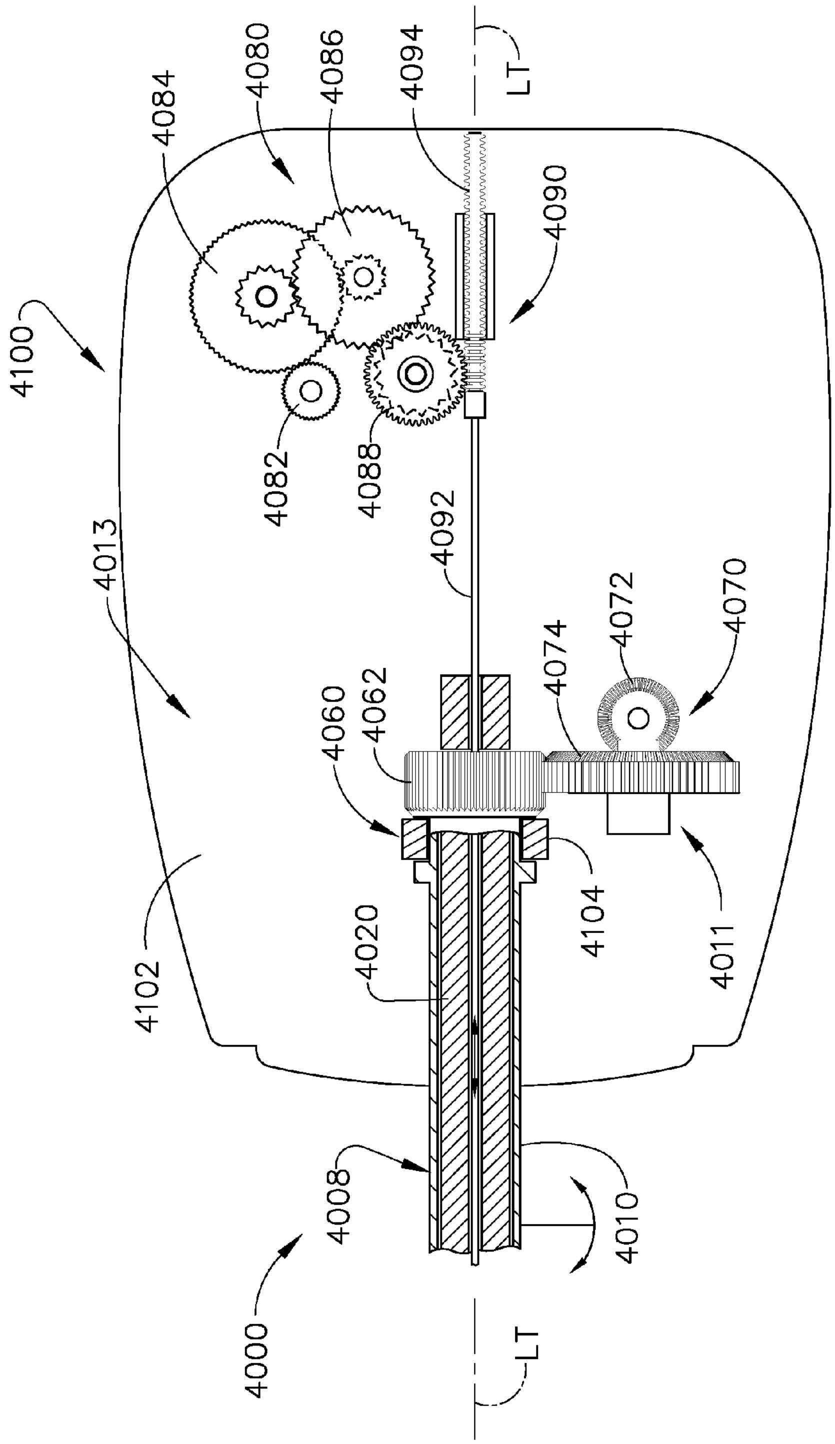


FIG. 103


4000
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4011
4013
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4062
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4072
4074
4080
4082
4084
4086
4088
4090
4092
4094
4100
4102
4104
LT
LT

FIG. 104

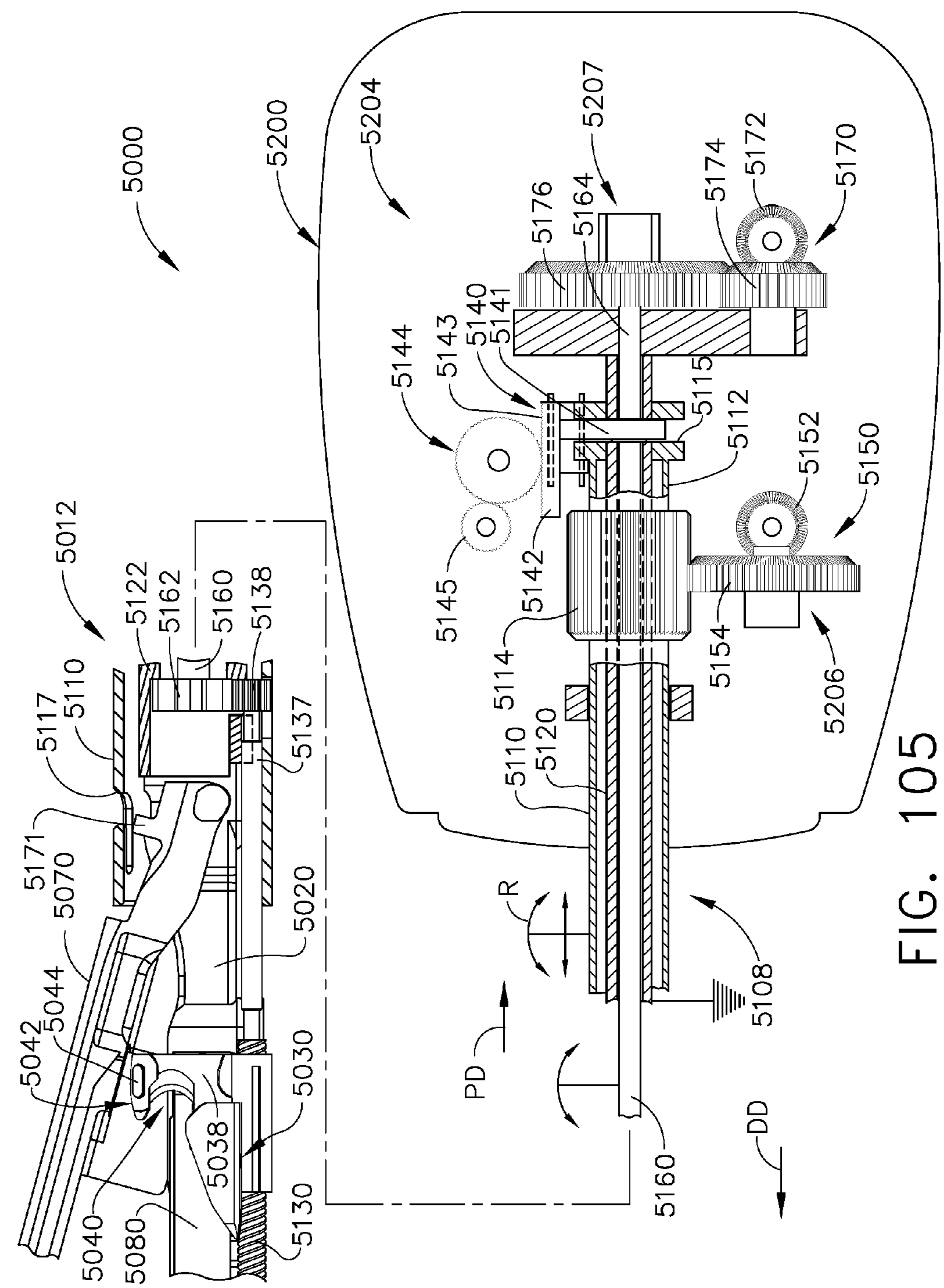
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FIG. 105

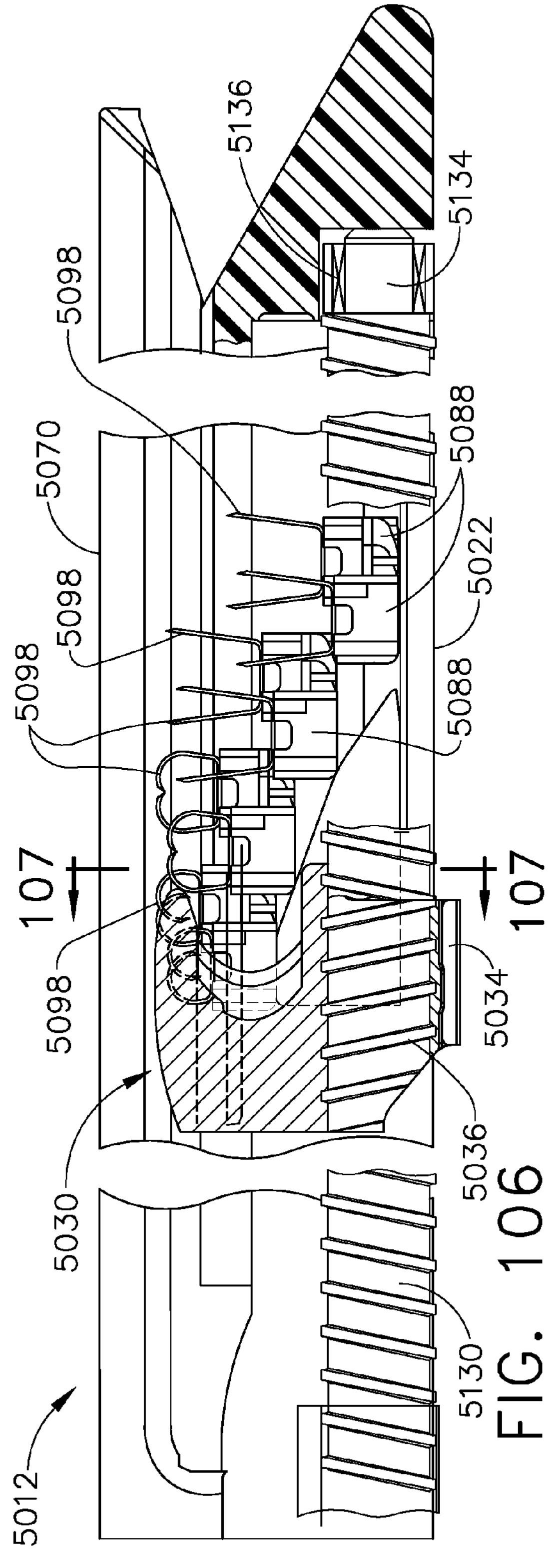

FIG. 106

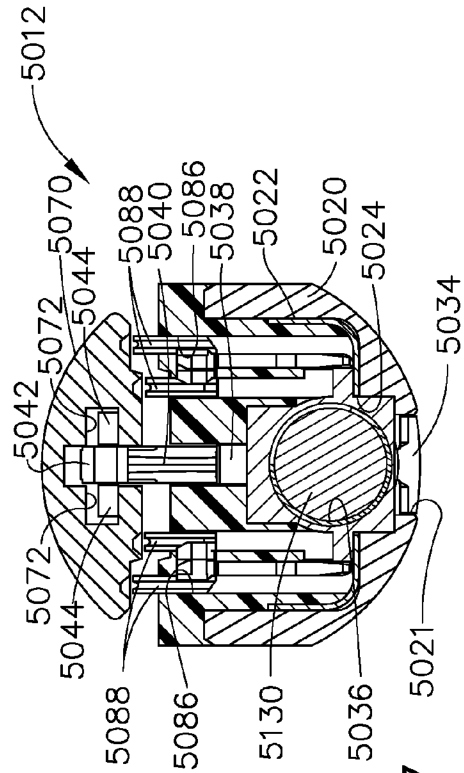

FIG. 107

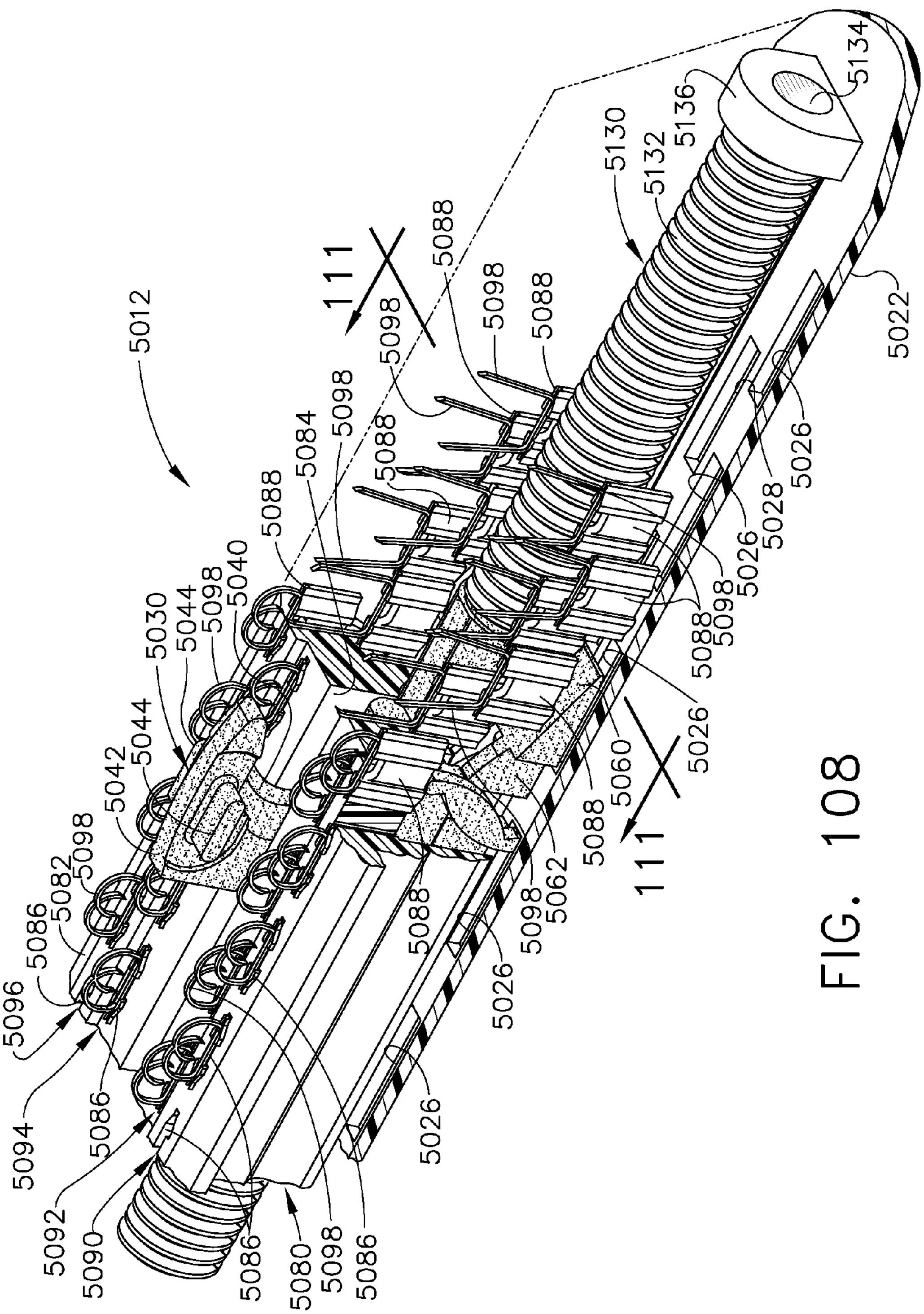

FIG. 108

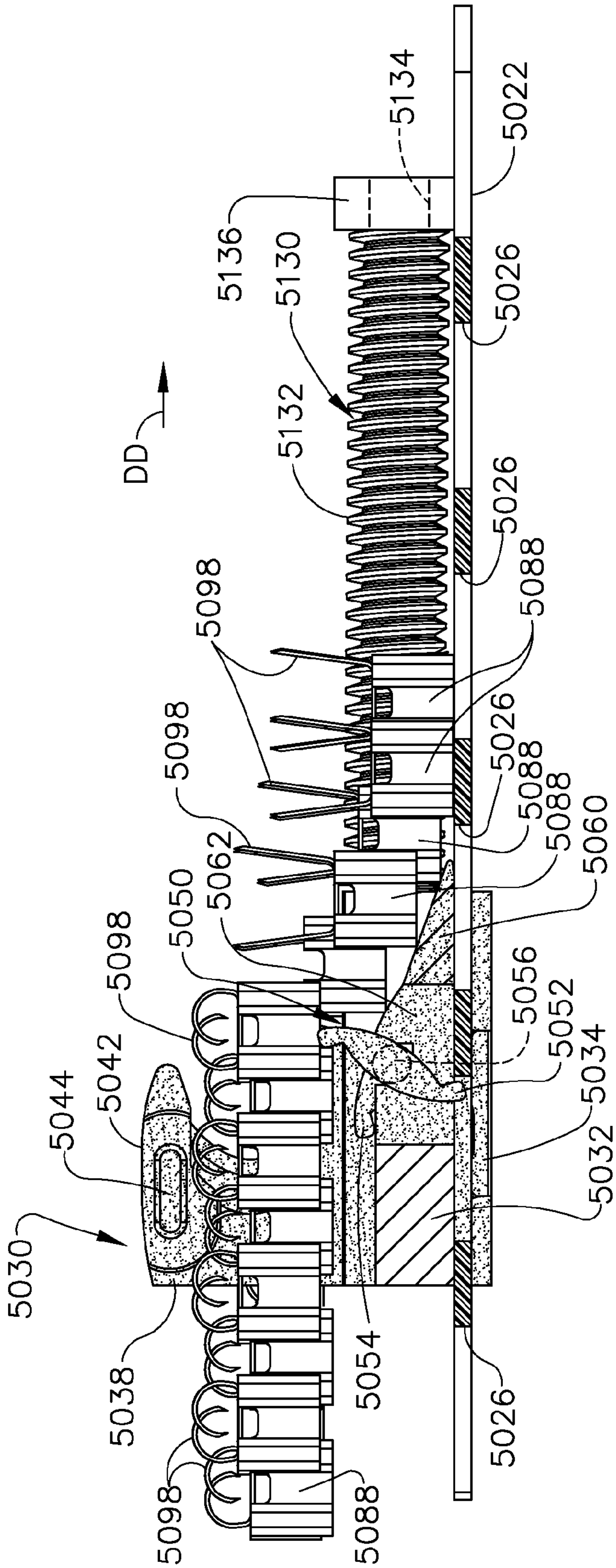
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FIG. 109

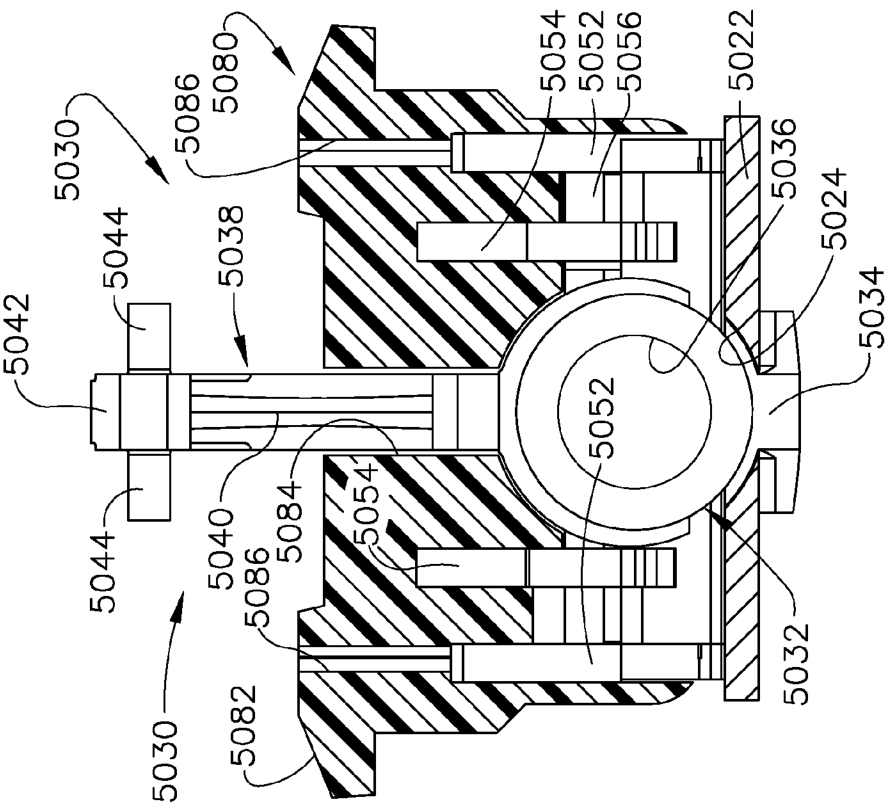


FIG. 111

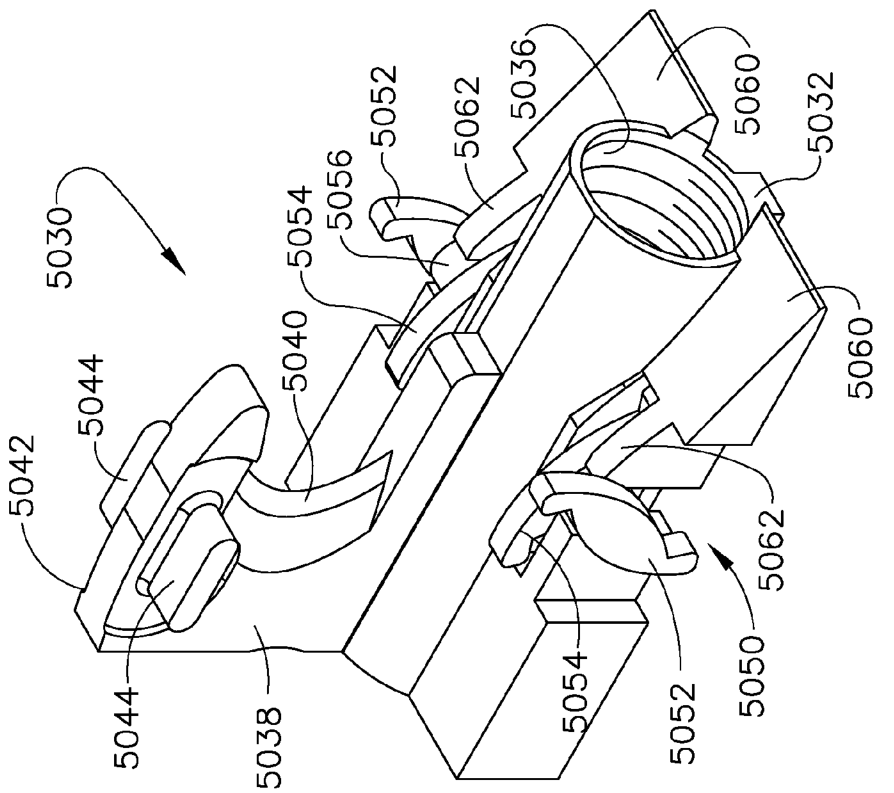


FIG. 110

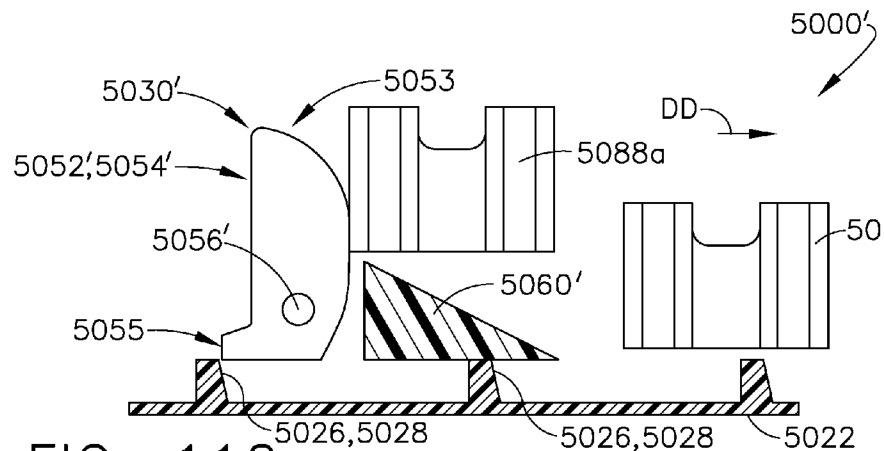


FIG. 112

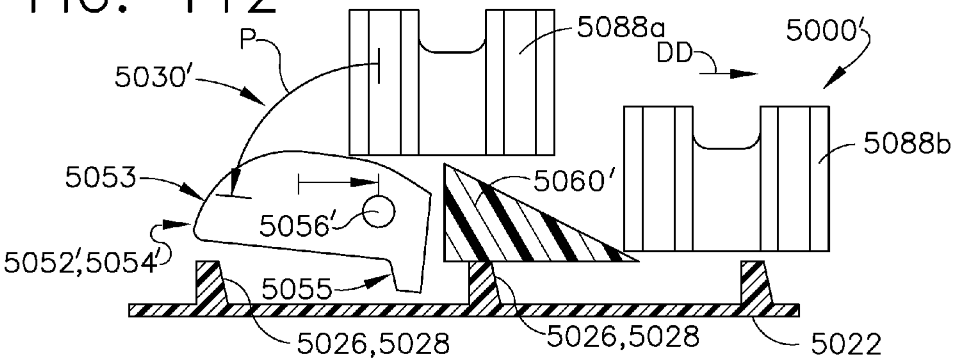


FIG. 113

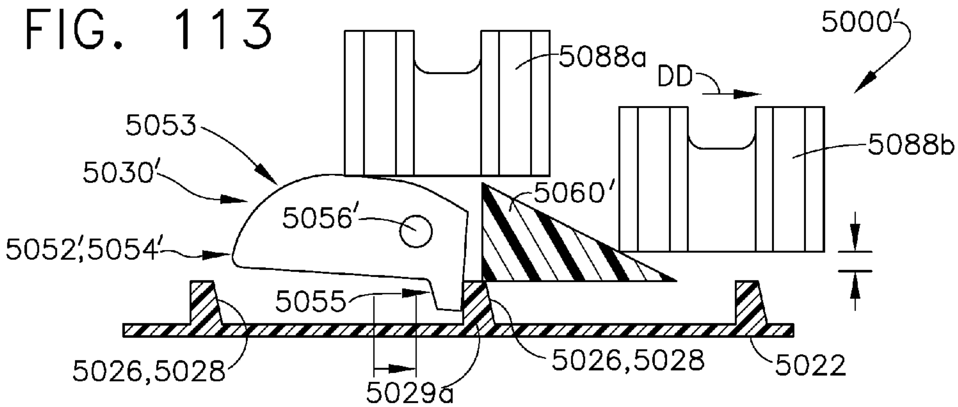


FIG. 114

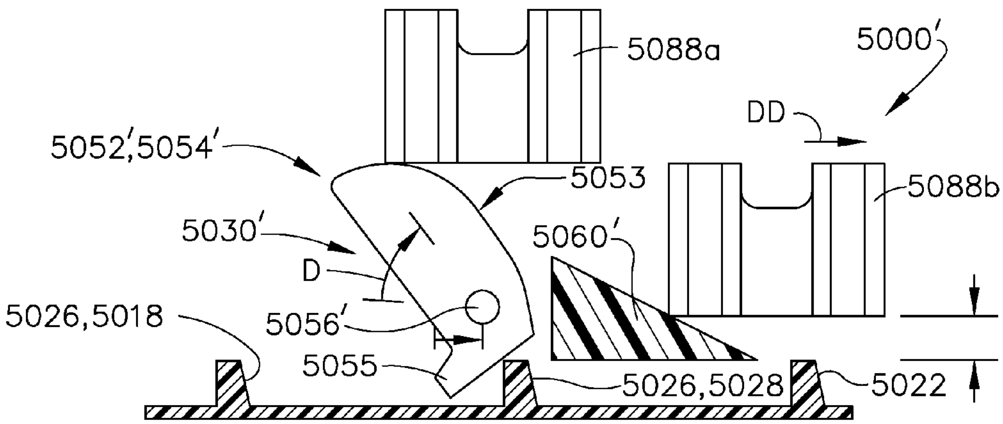


FIG. 115

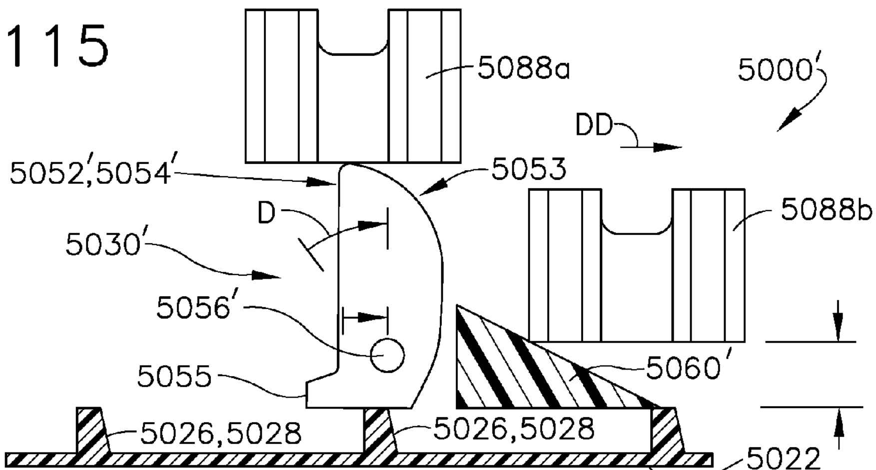


FIG. 116

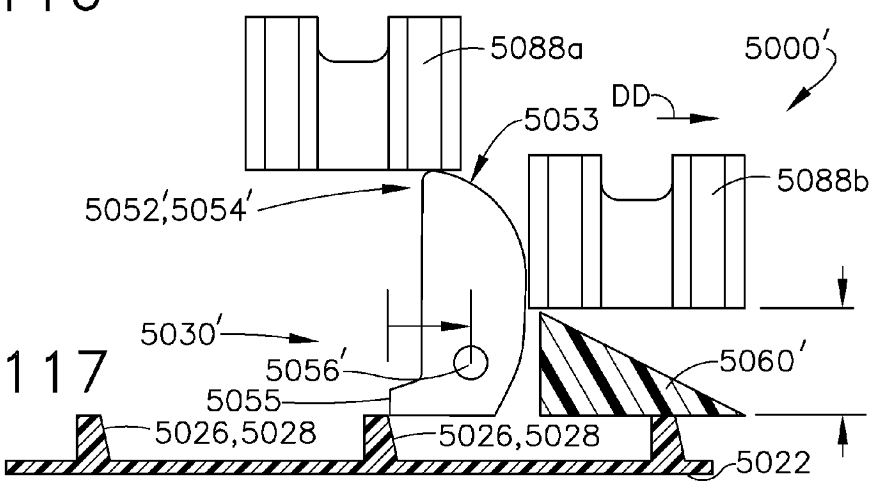
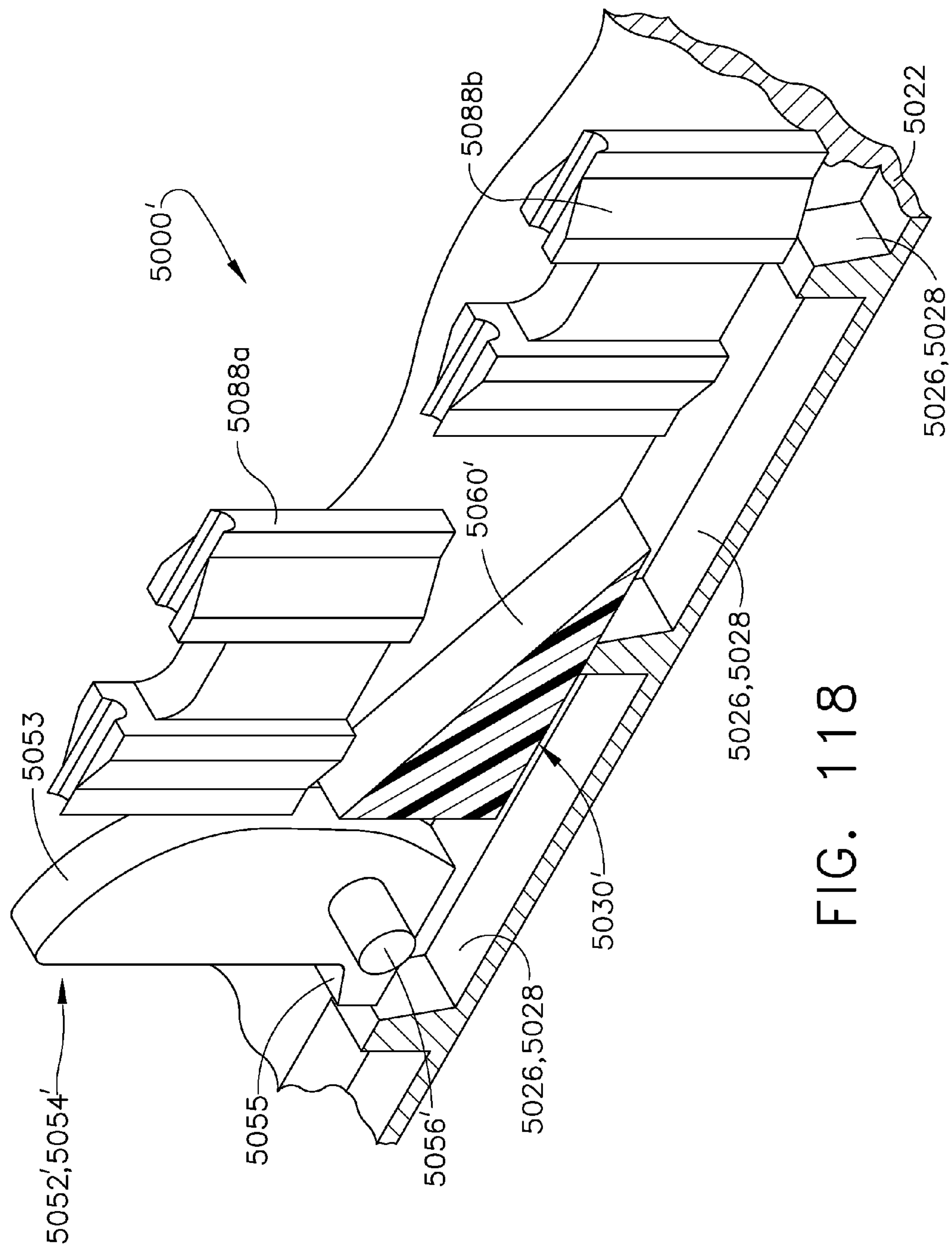


FIG. 117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5056′

FIG. 118

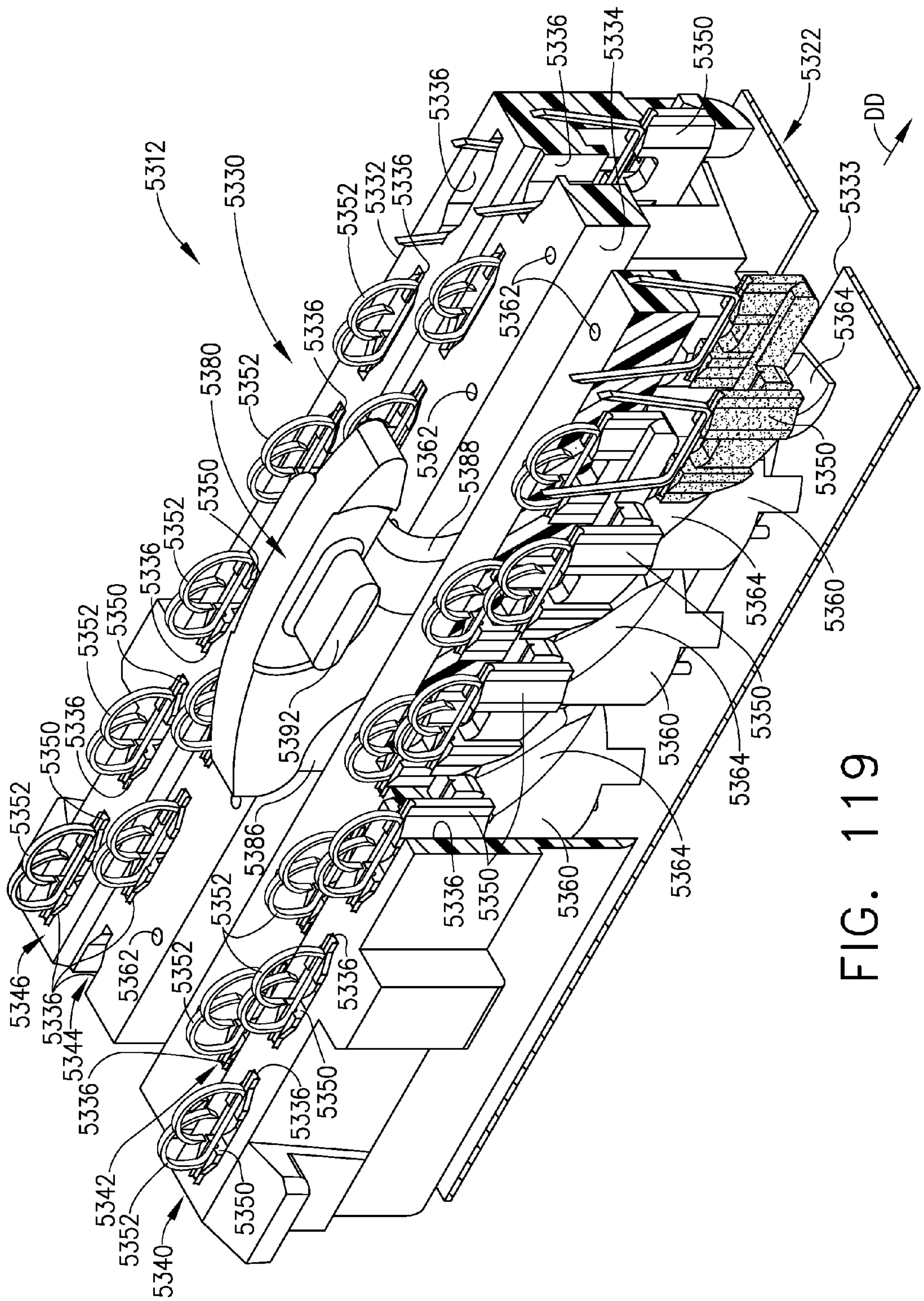
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FIG. 119

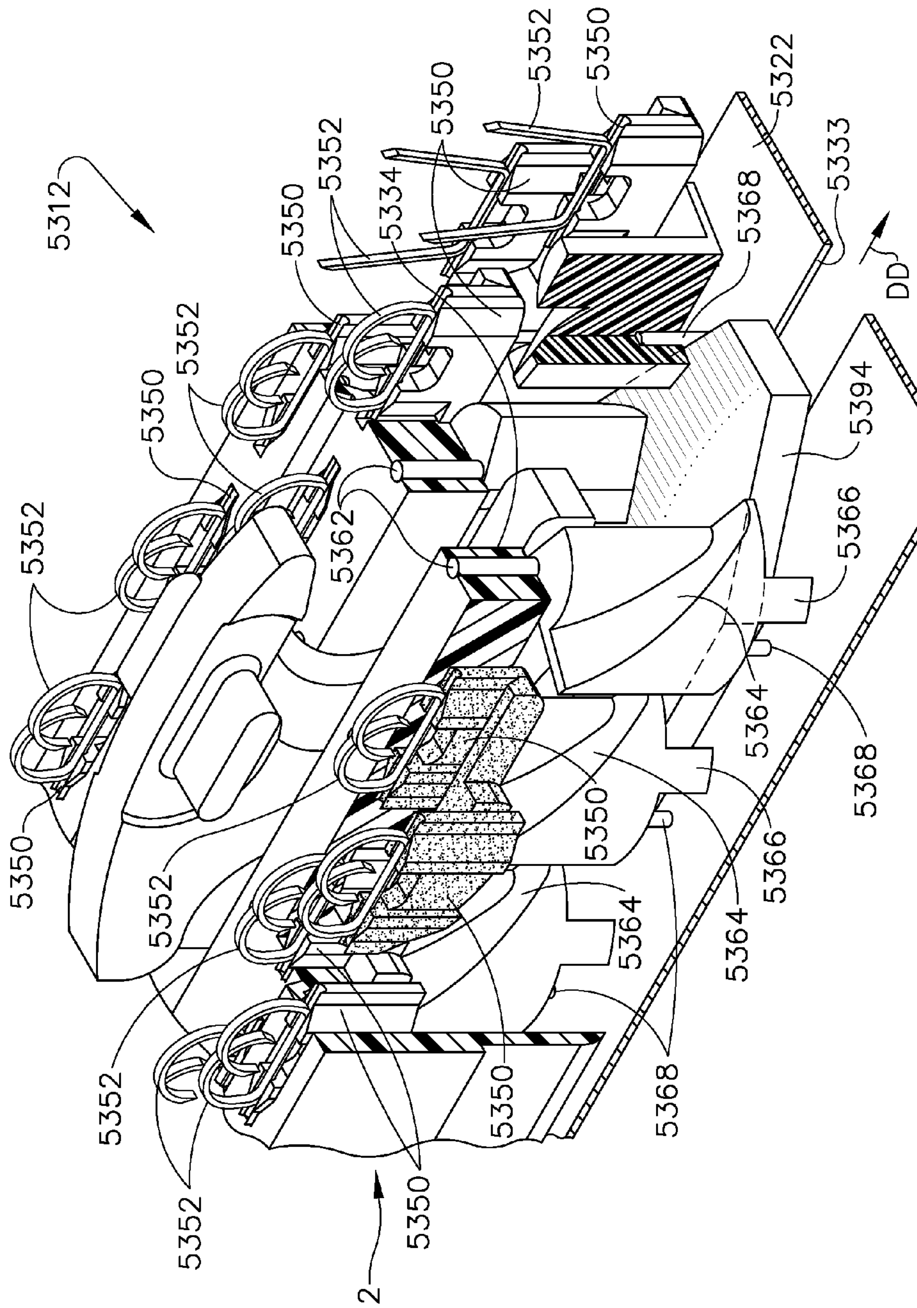
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FIG. 120

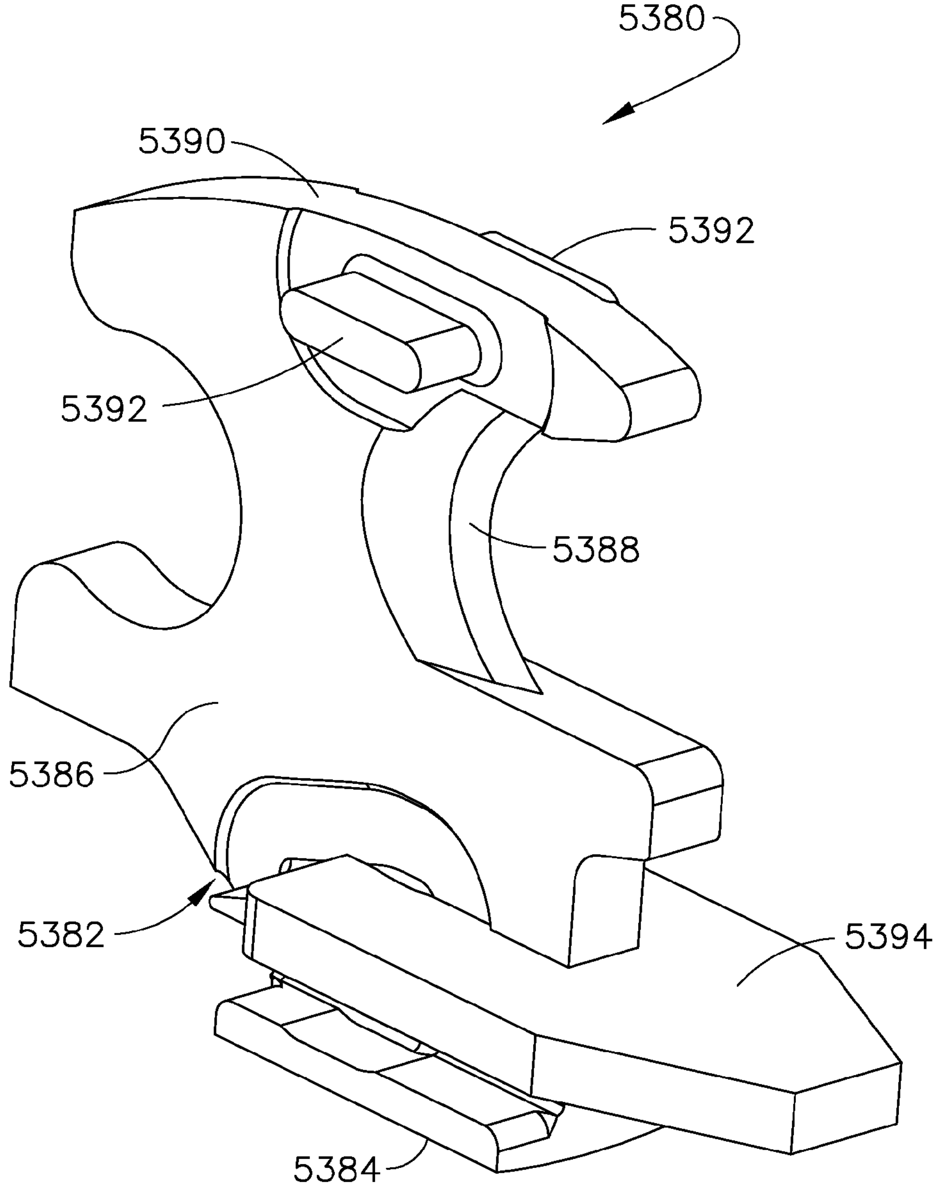

FIG. 121

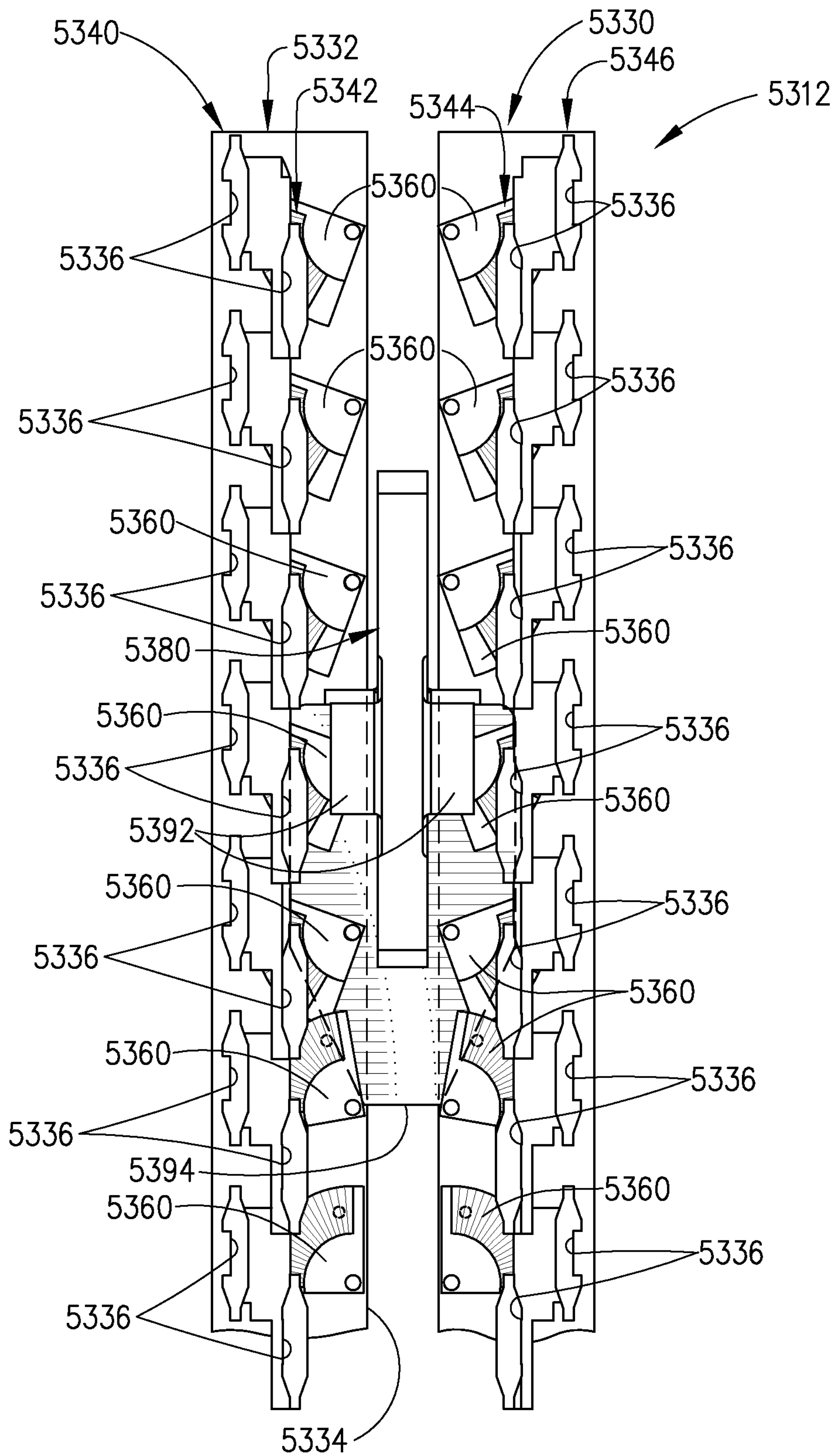
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FIG. 122

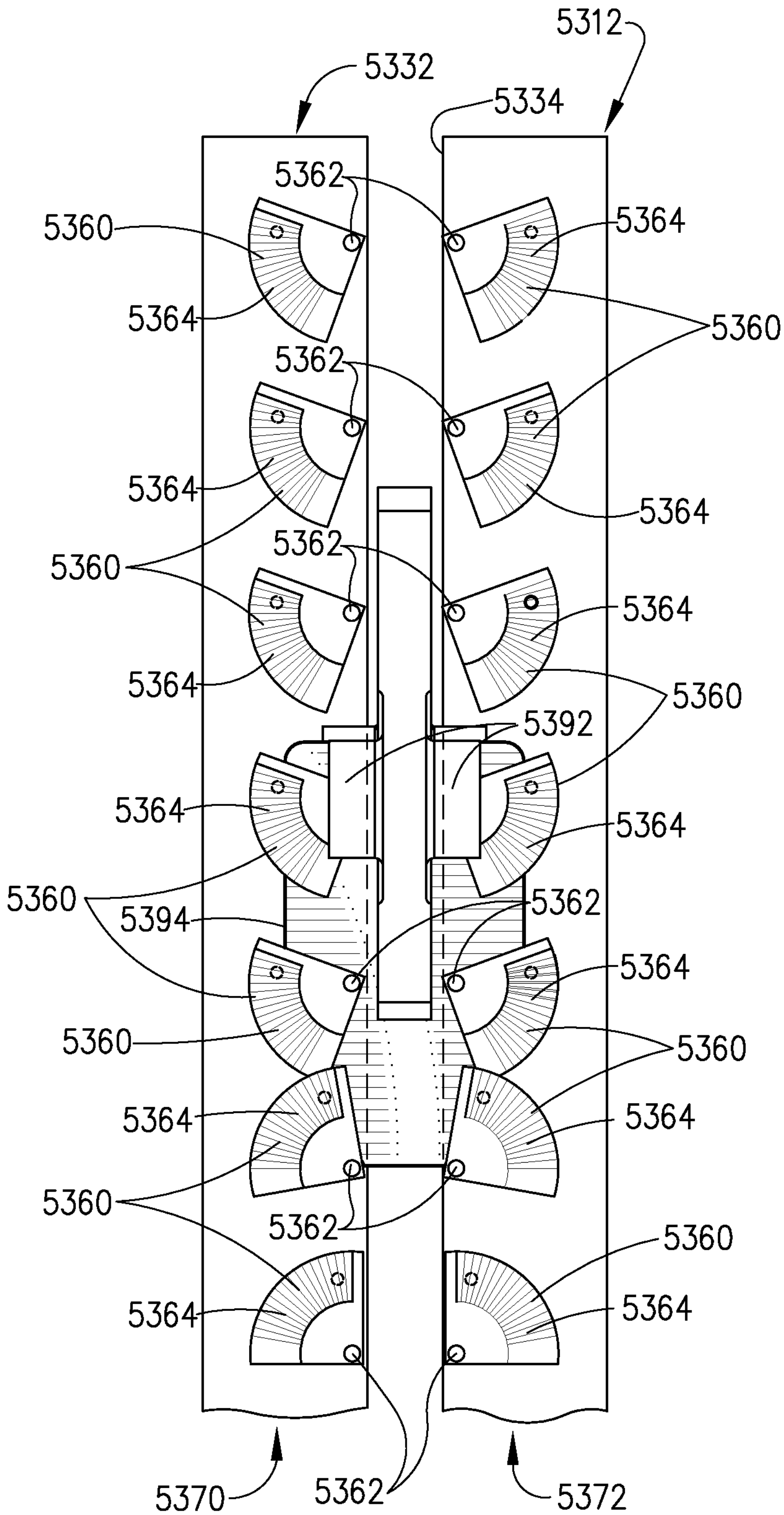

FIG. 123

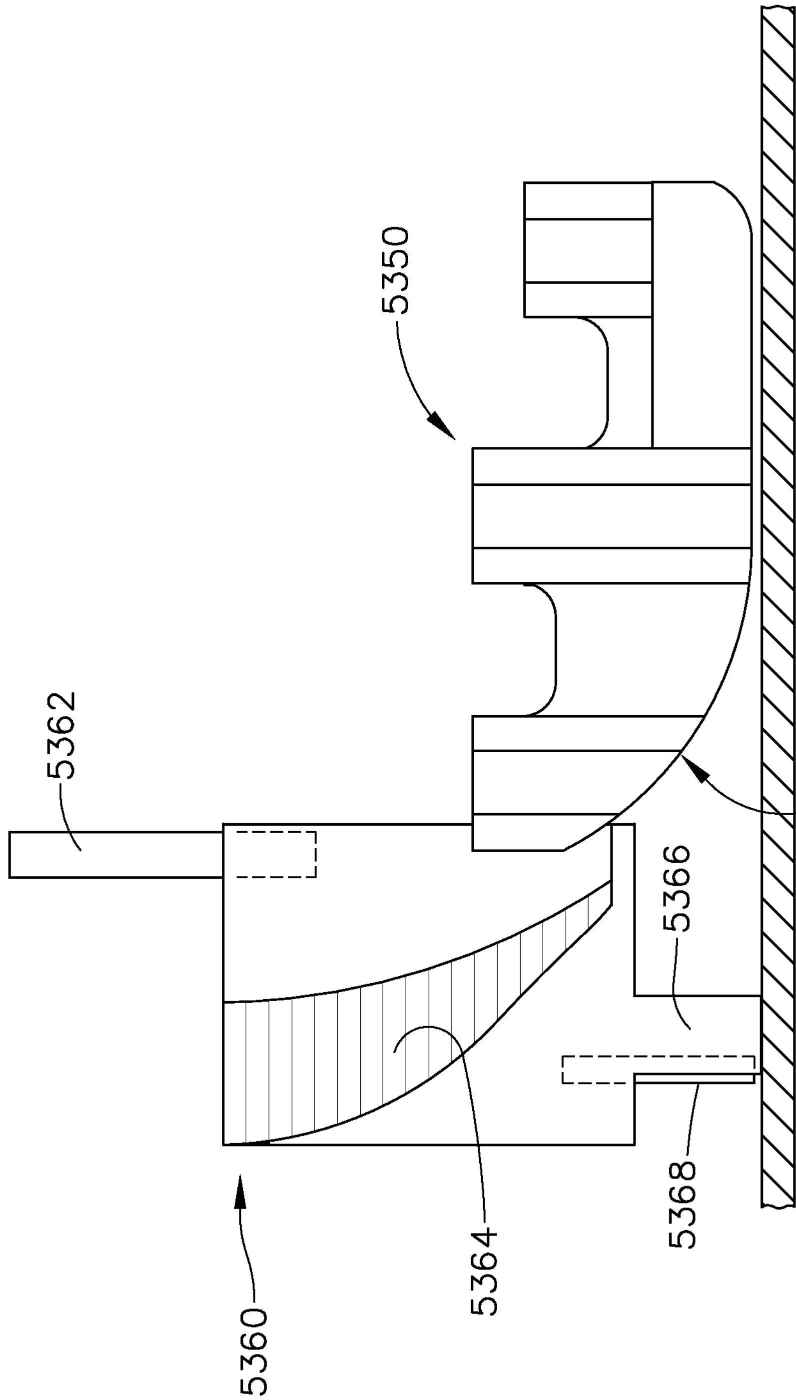

FIG. 124

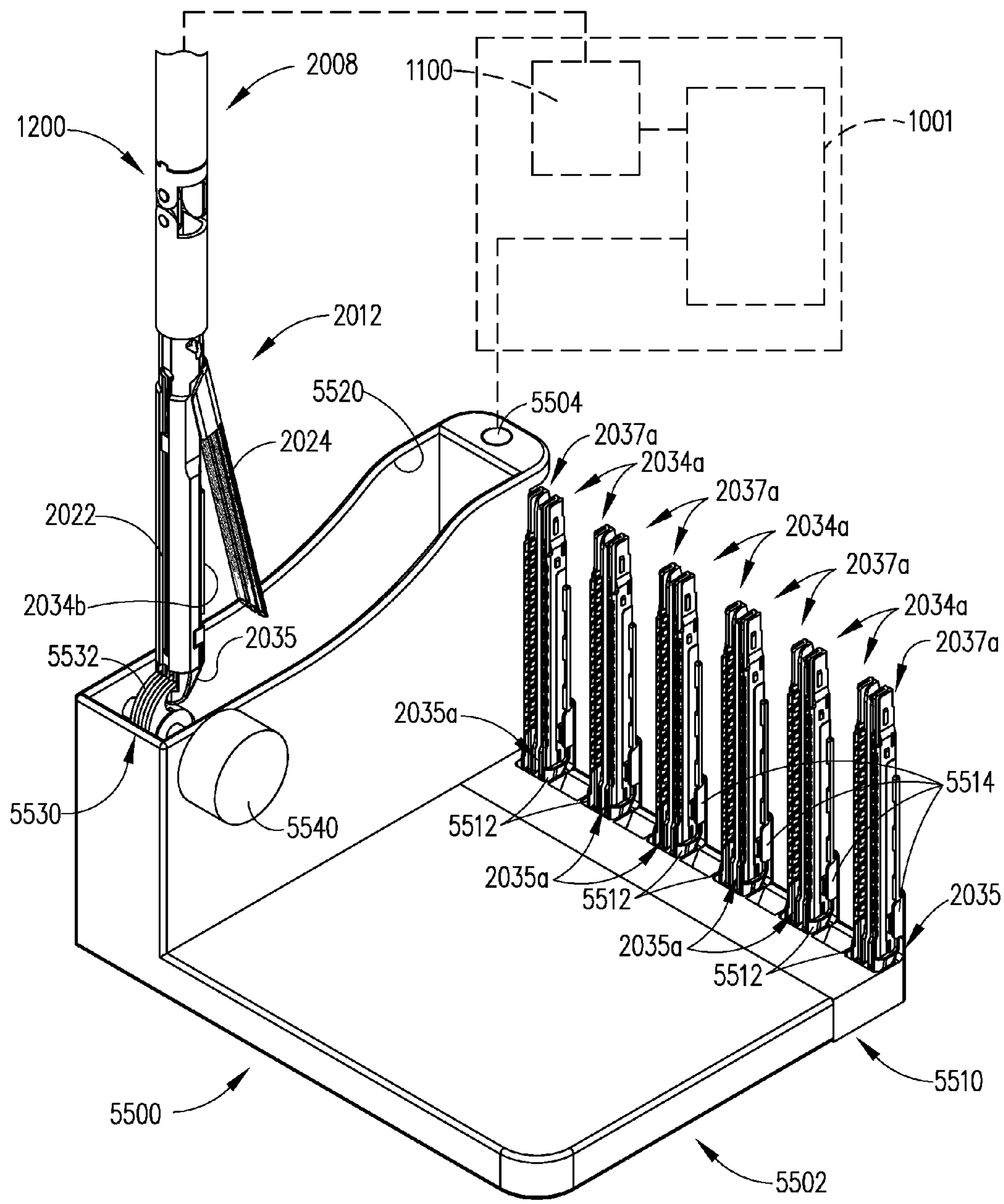

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FIG. 125

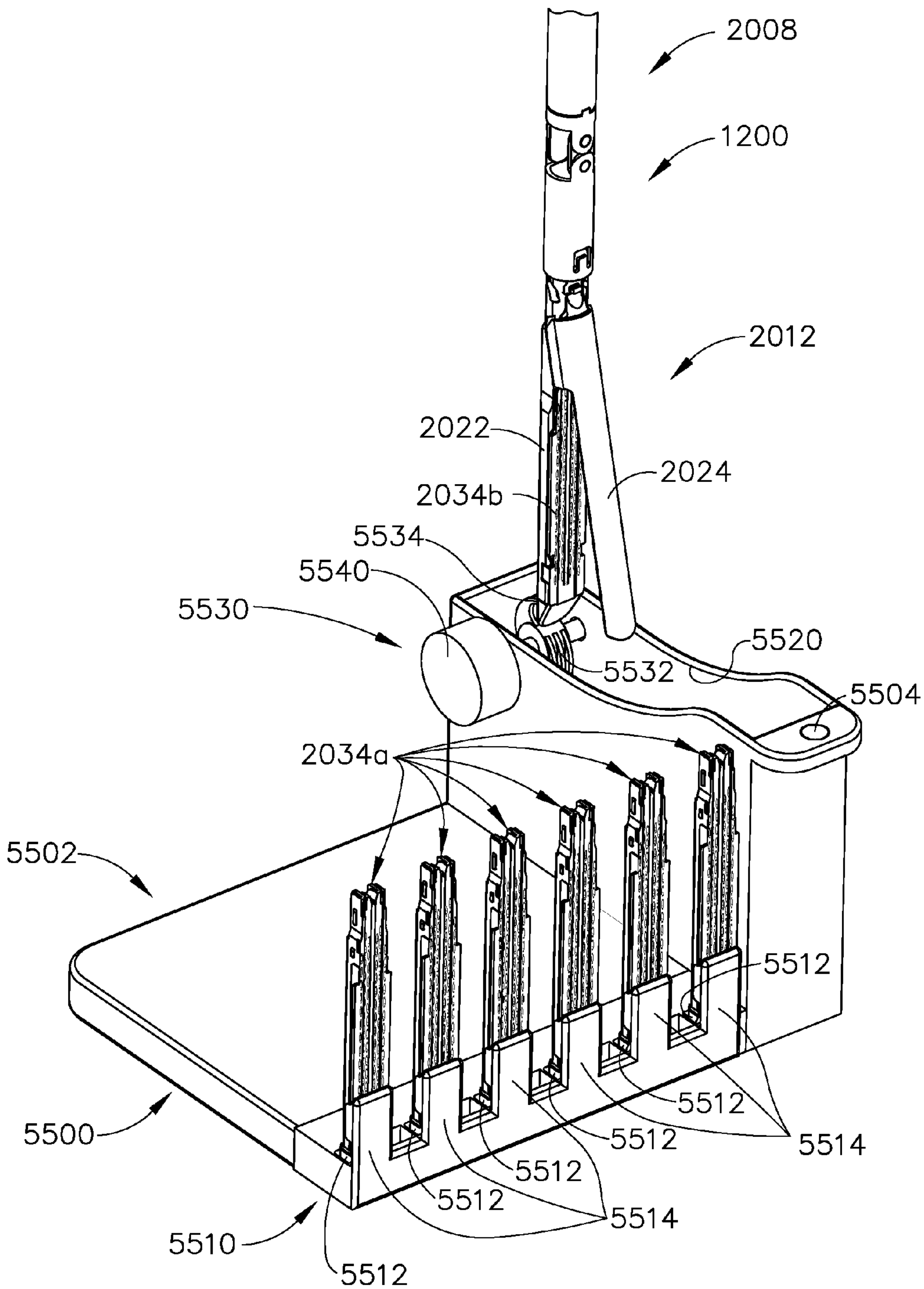
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FIG. 126

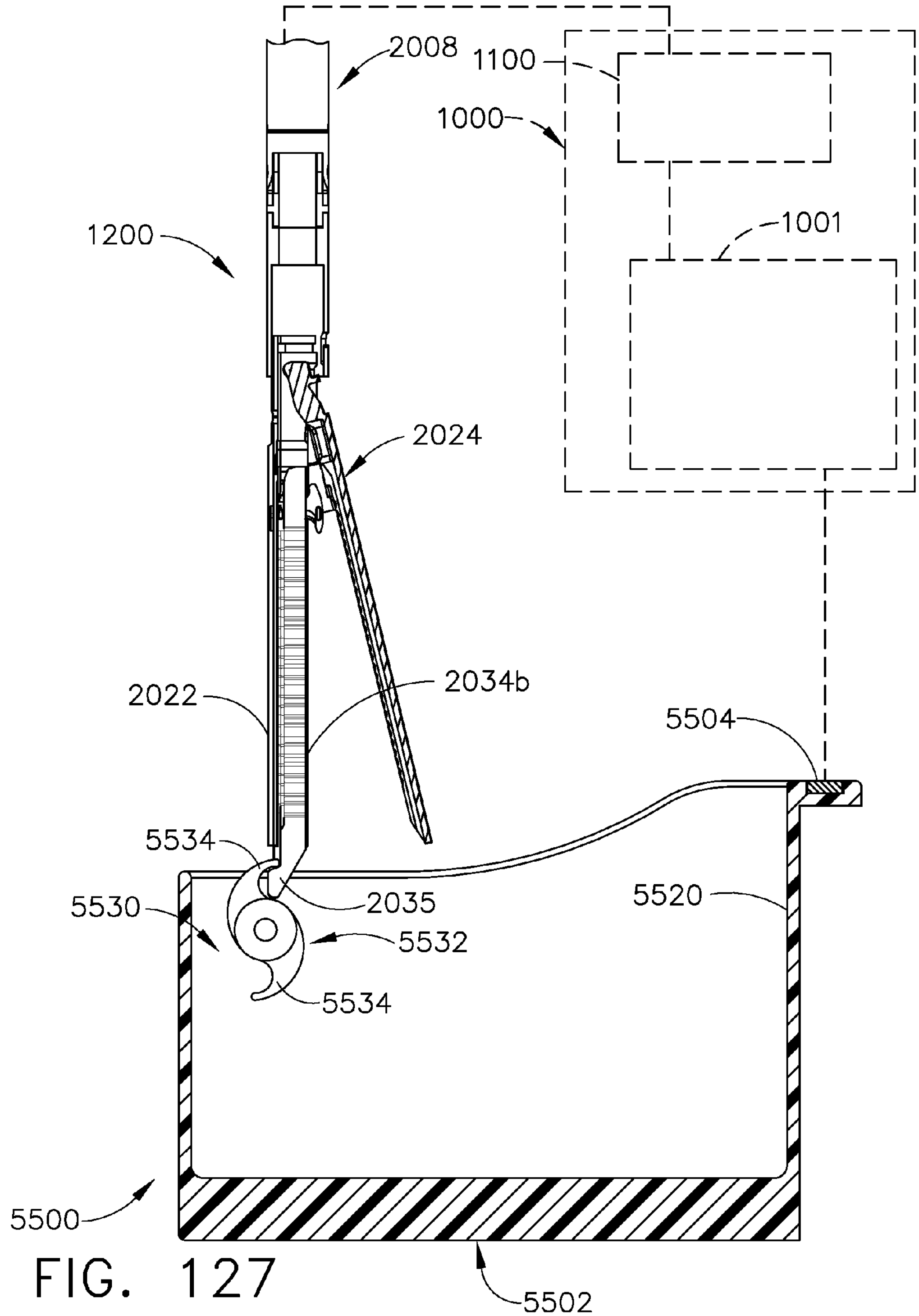
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FIG. 127

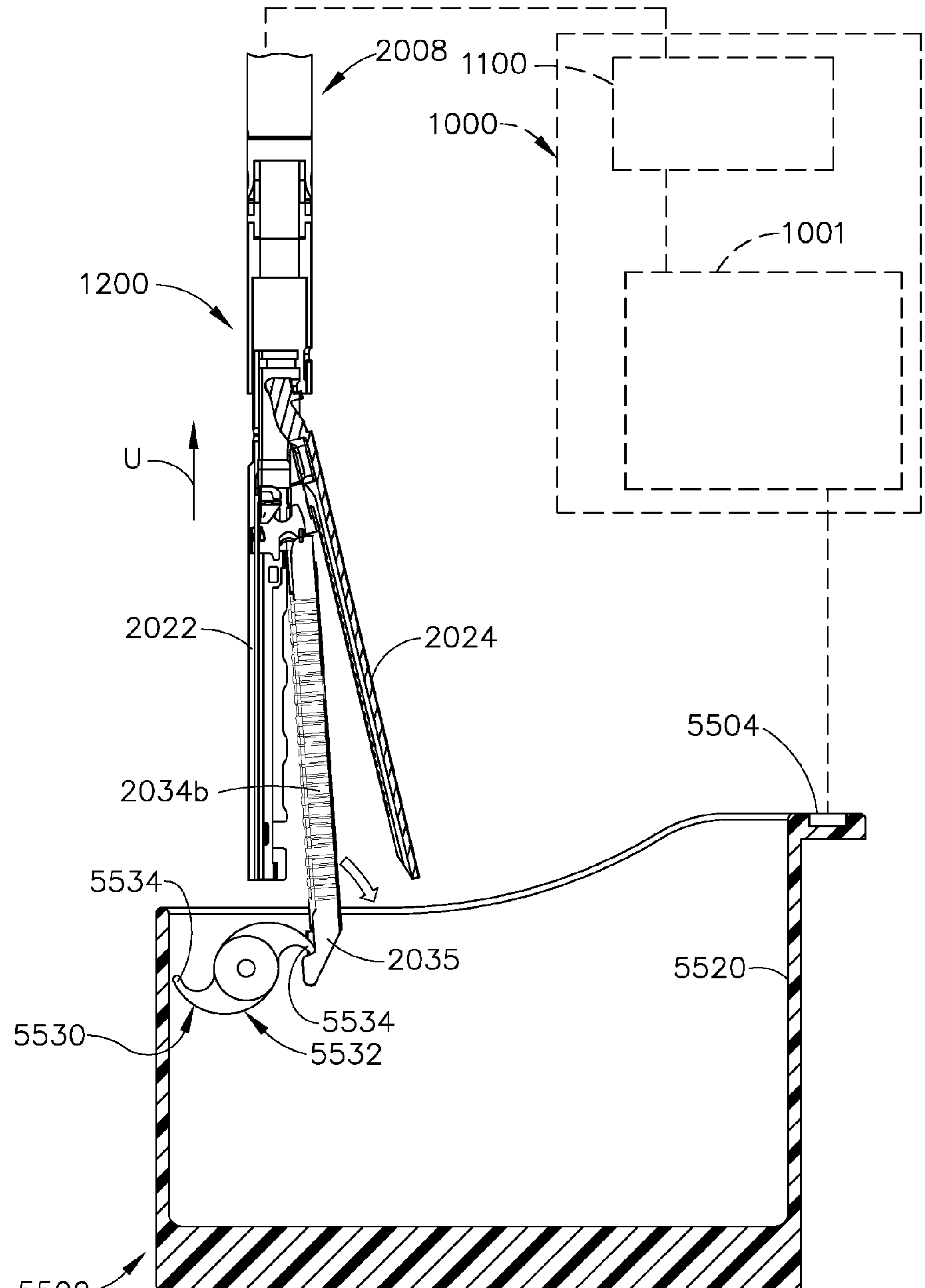
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FIG. 128

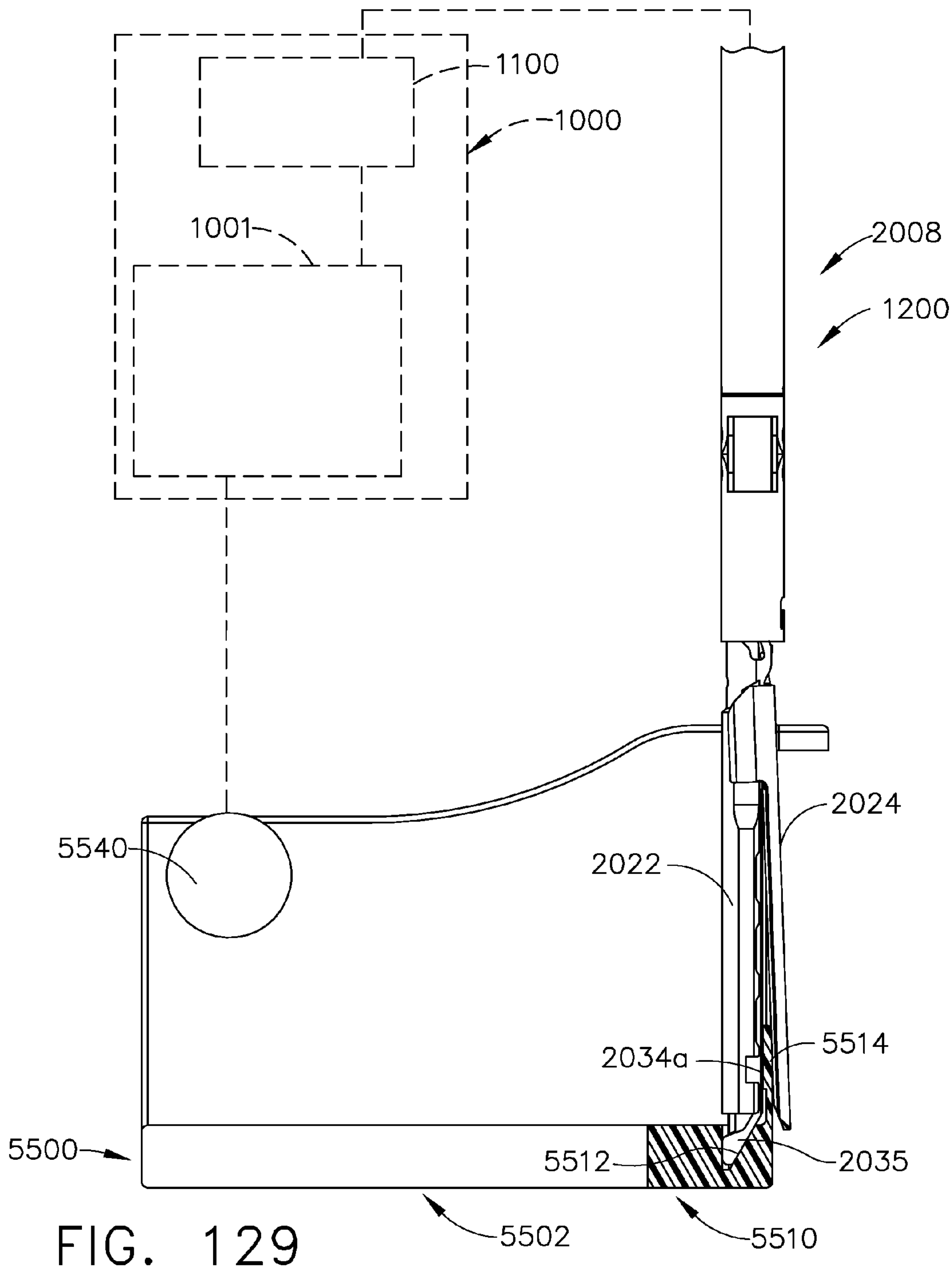

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FIG. 129

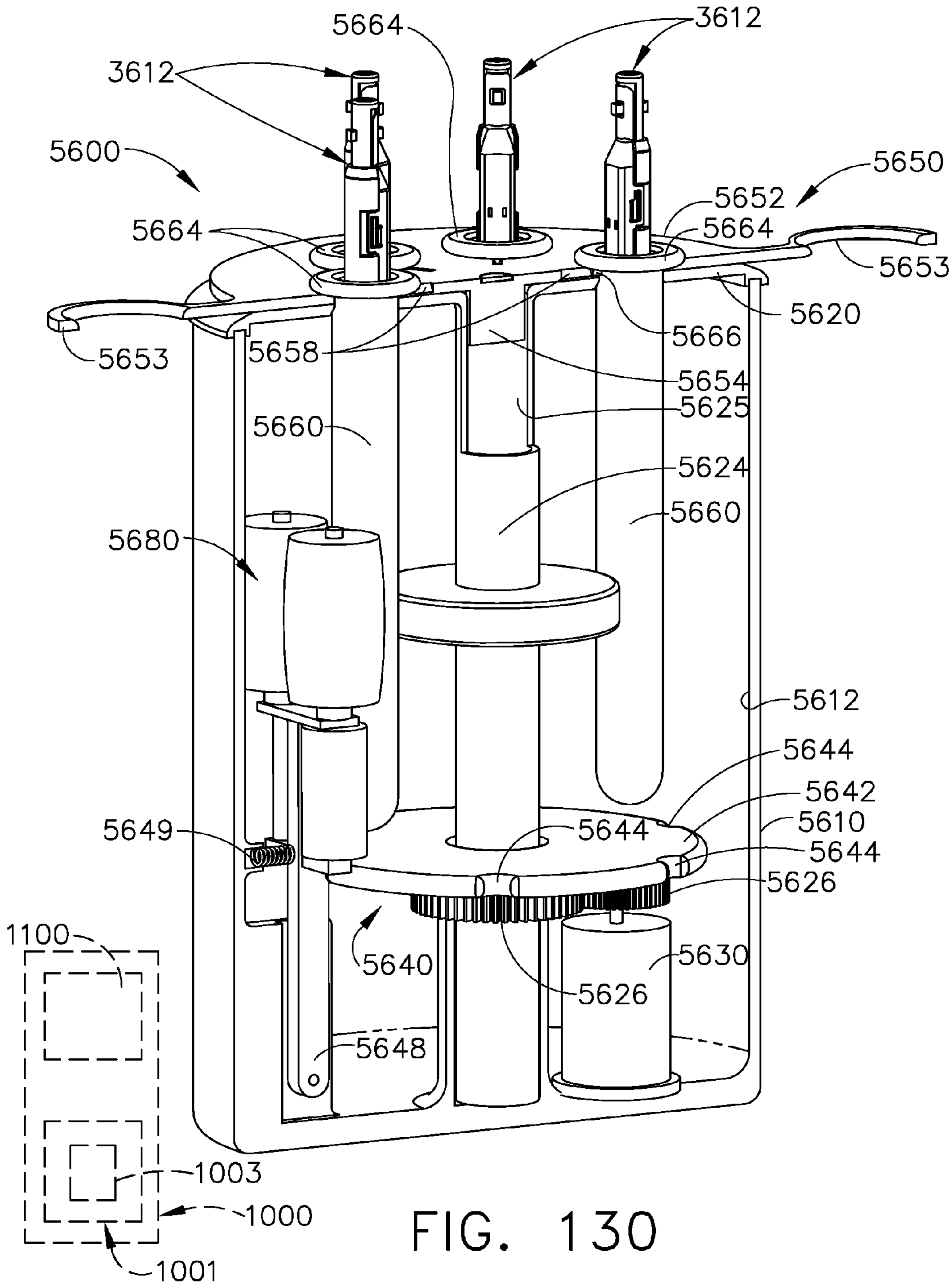
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FIG. 130

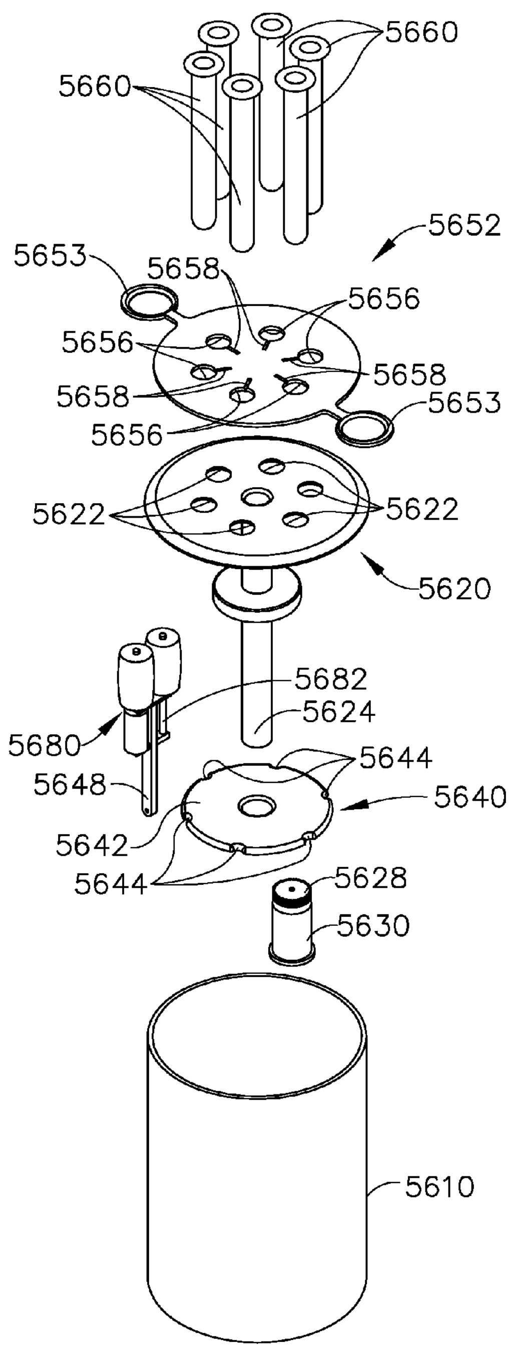

FIG. 131

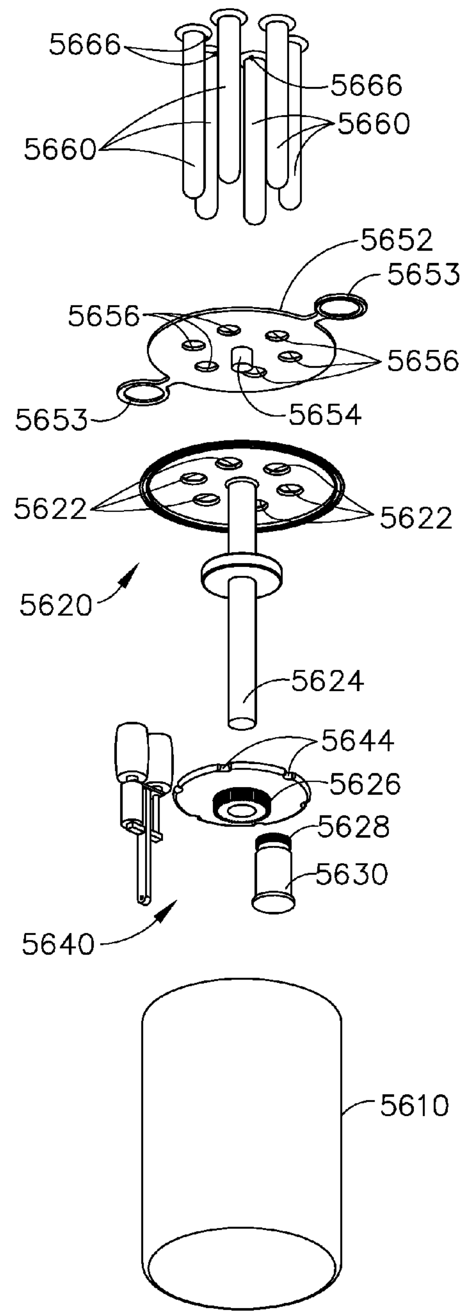

FIG. 132

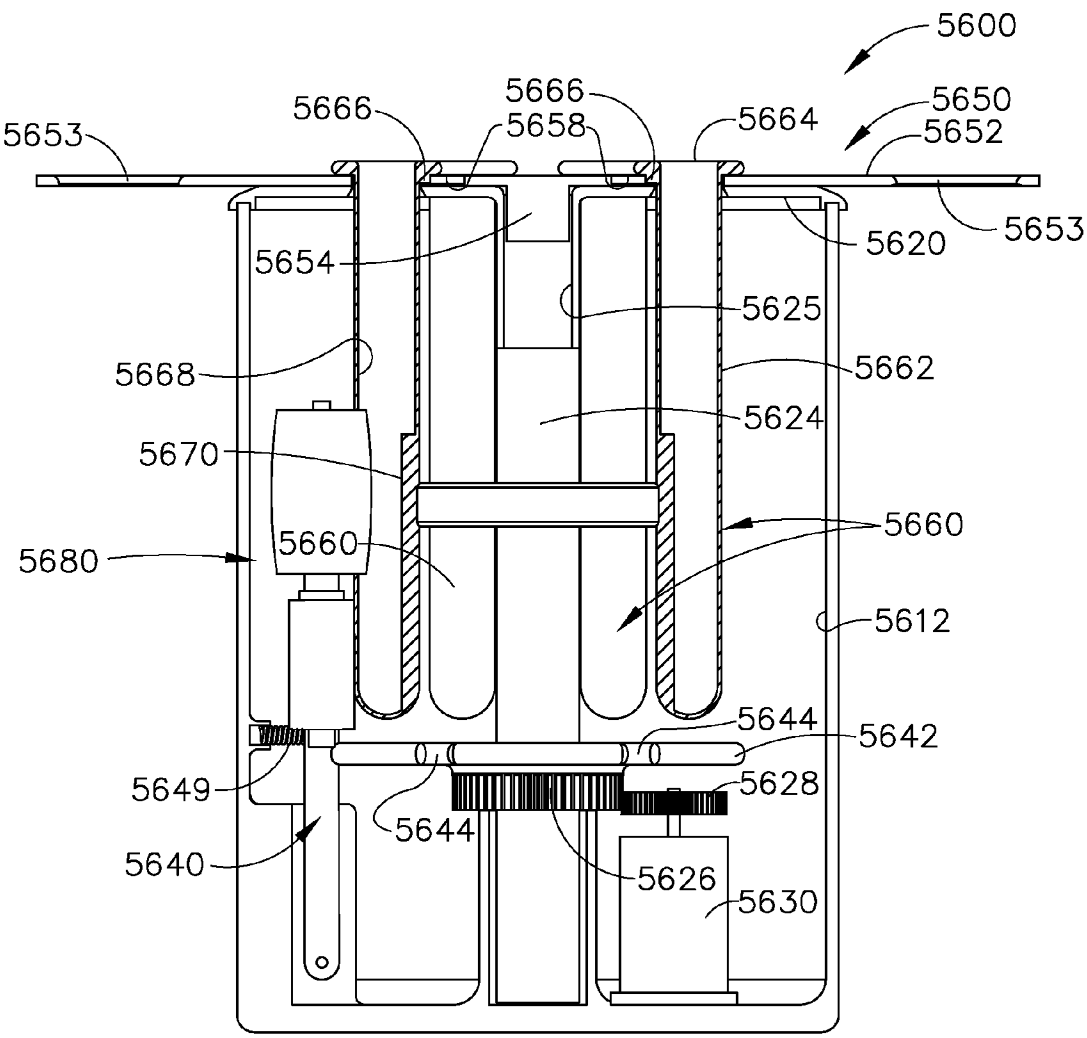
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FIG. 133

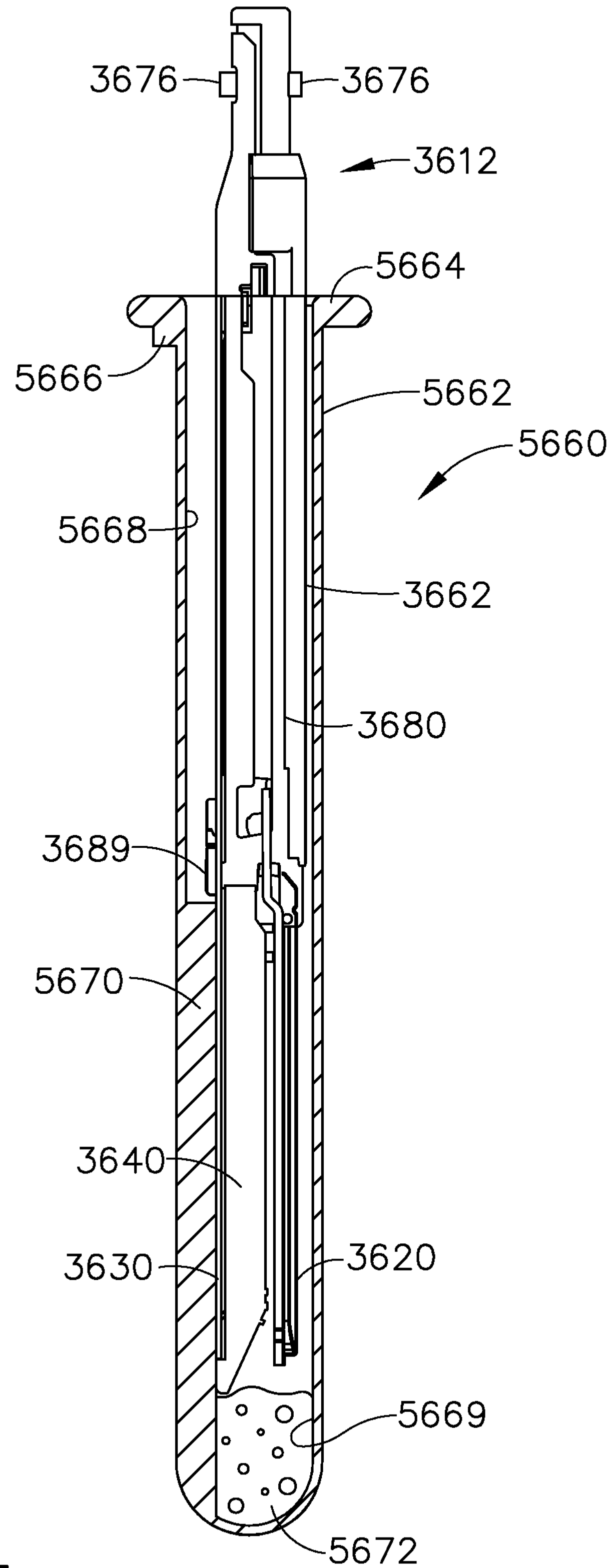
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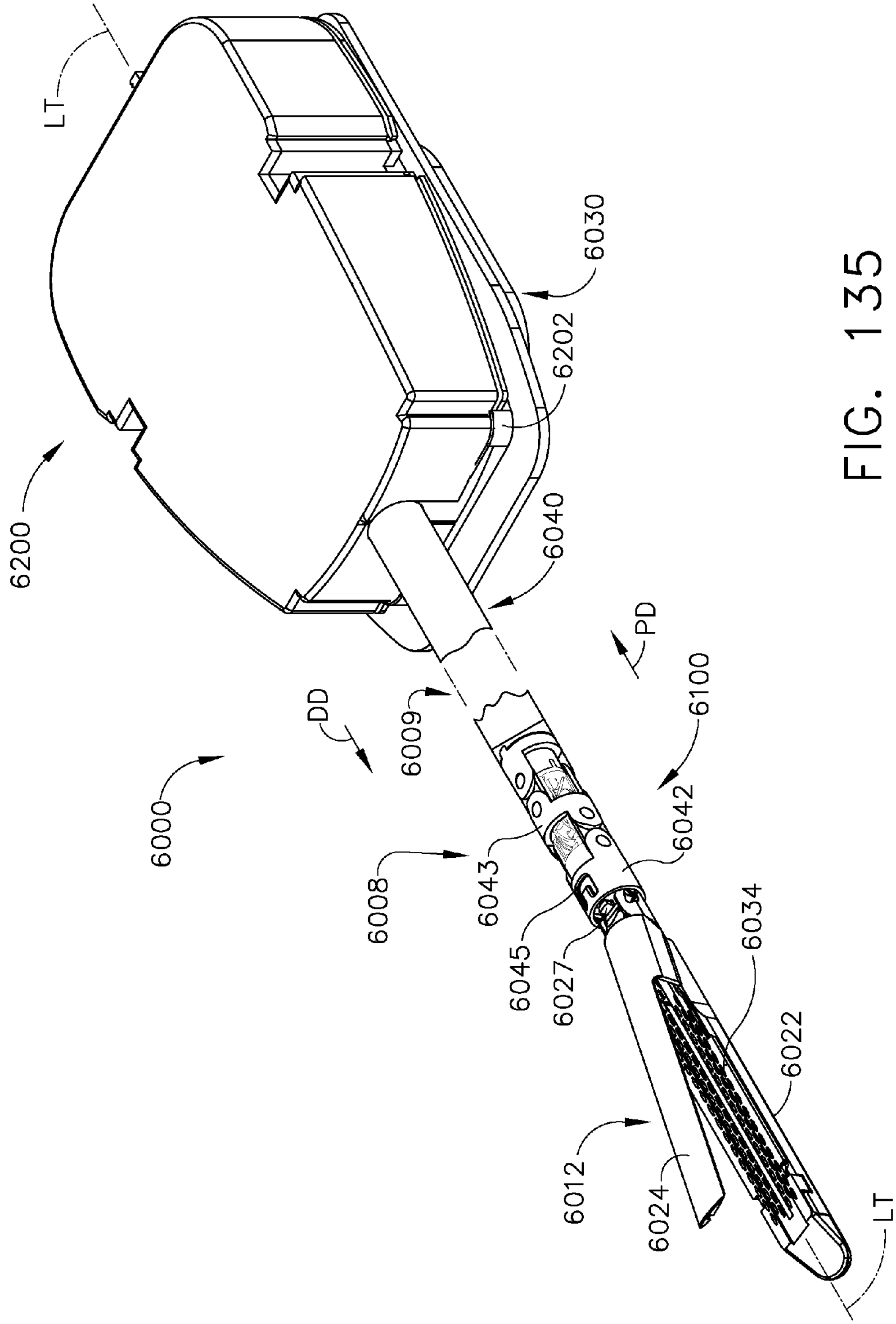
FIG. 134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LT

FIG. 135

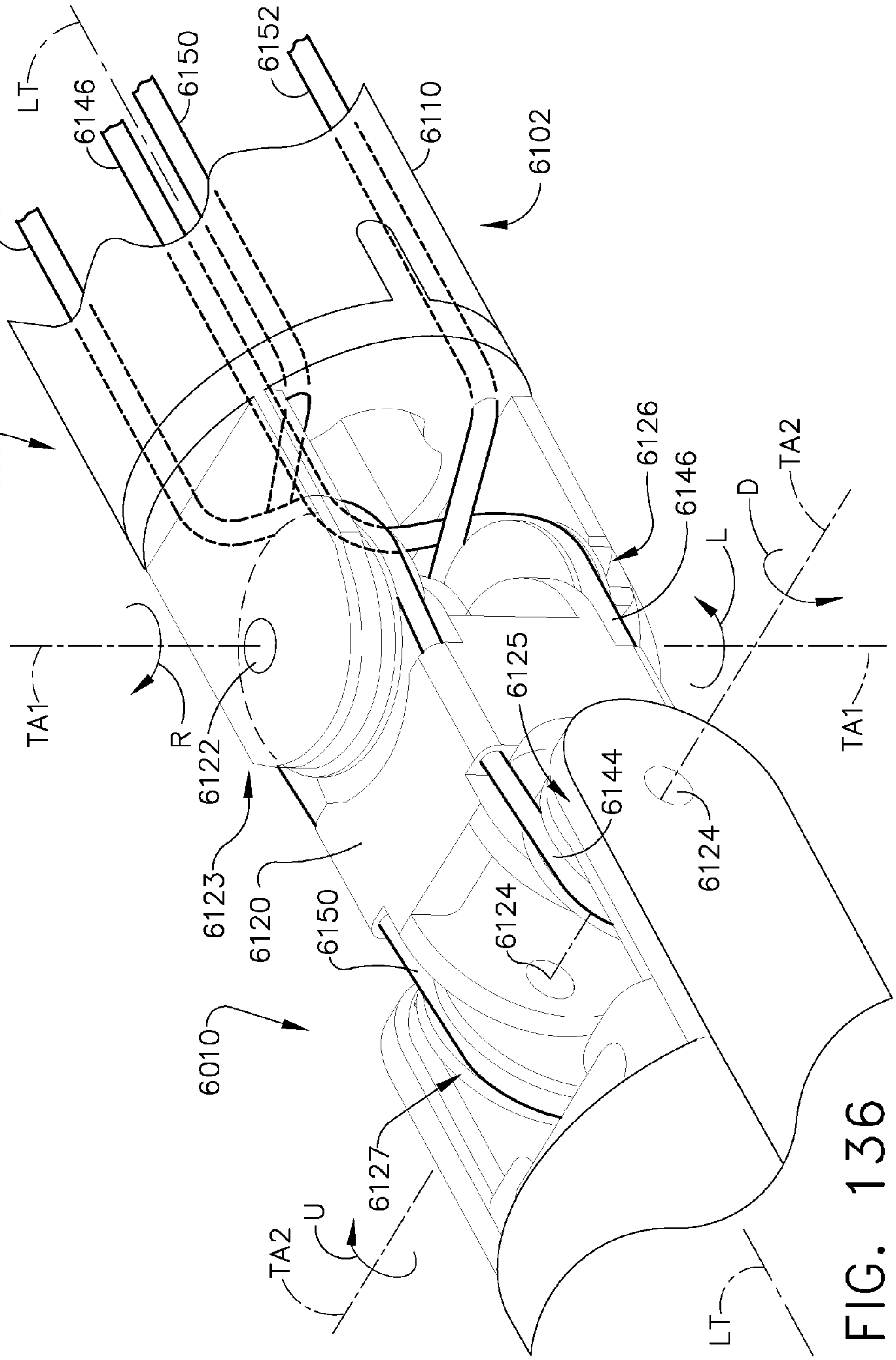
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FIG. 136

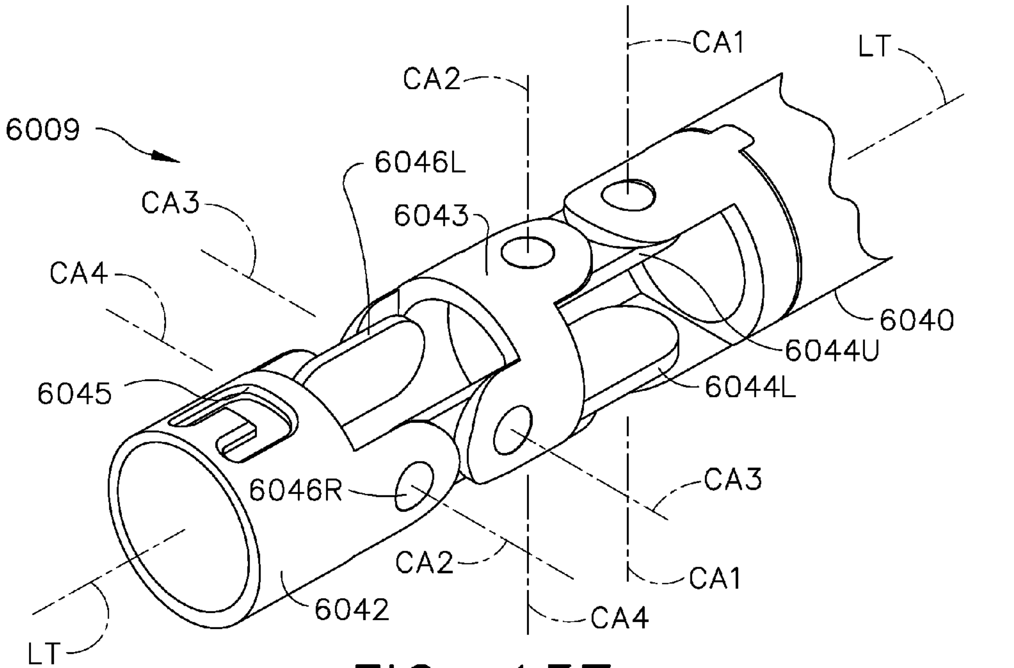

FIG. 137

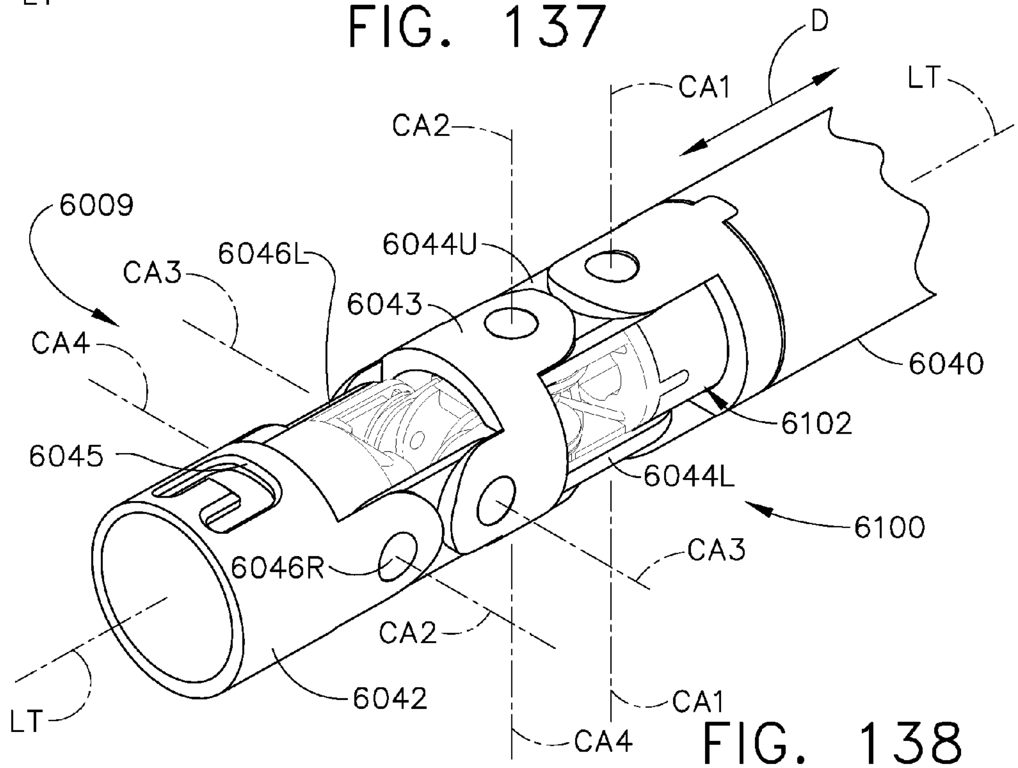

FIG. 138

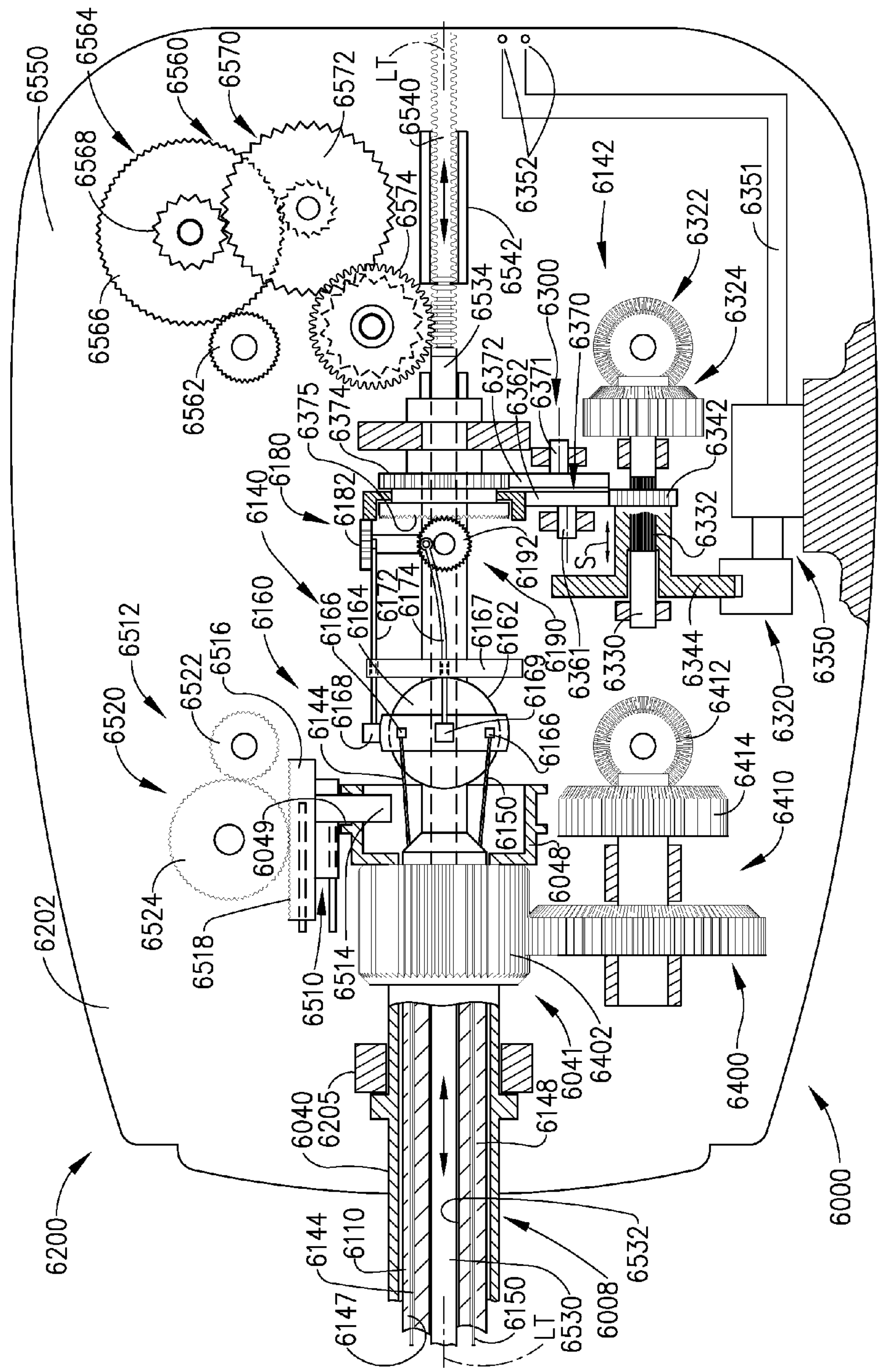

FIG. 139

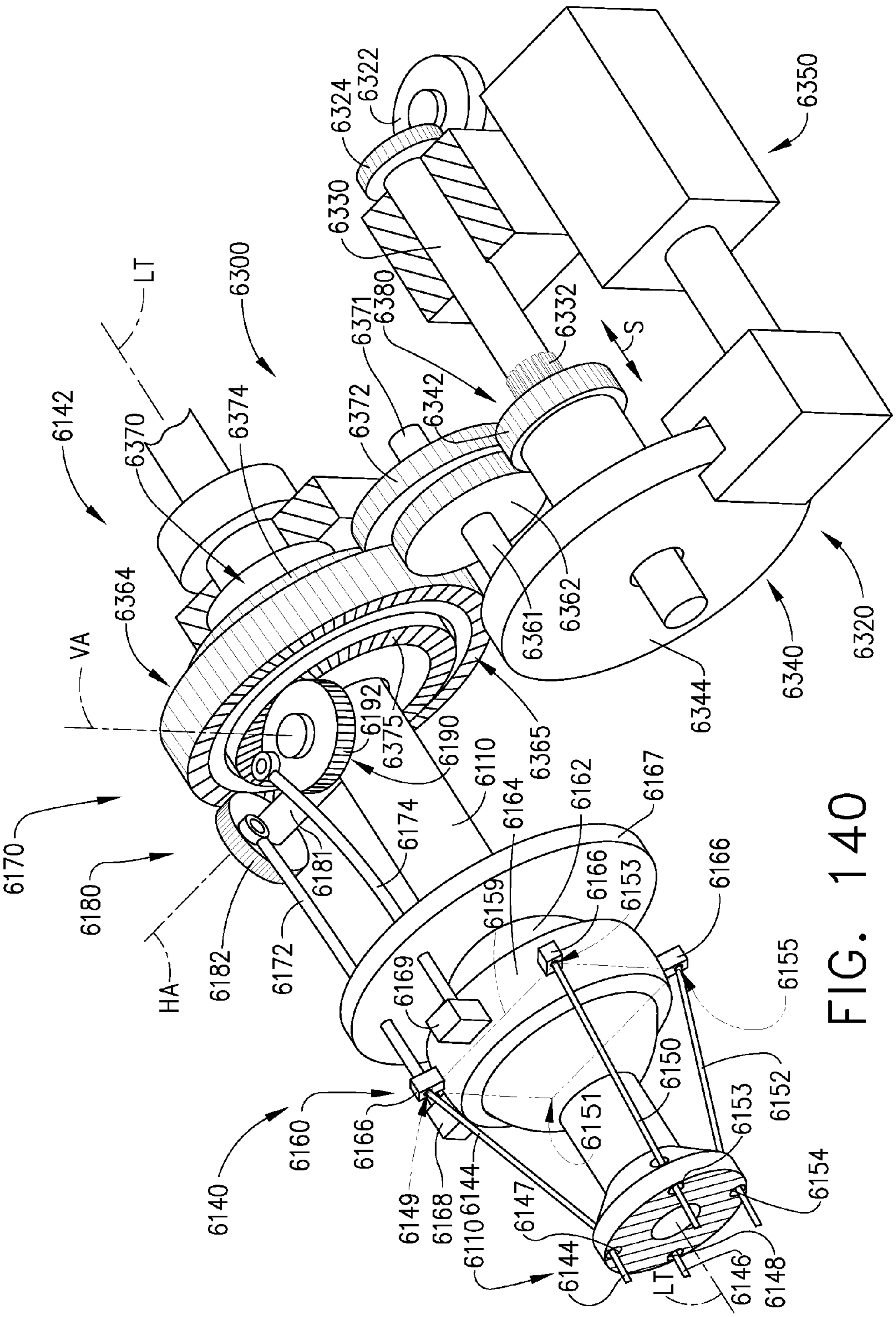
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FIG. 140

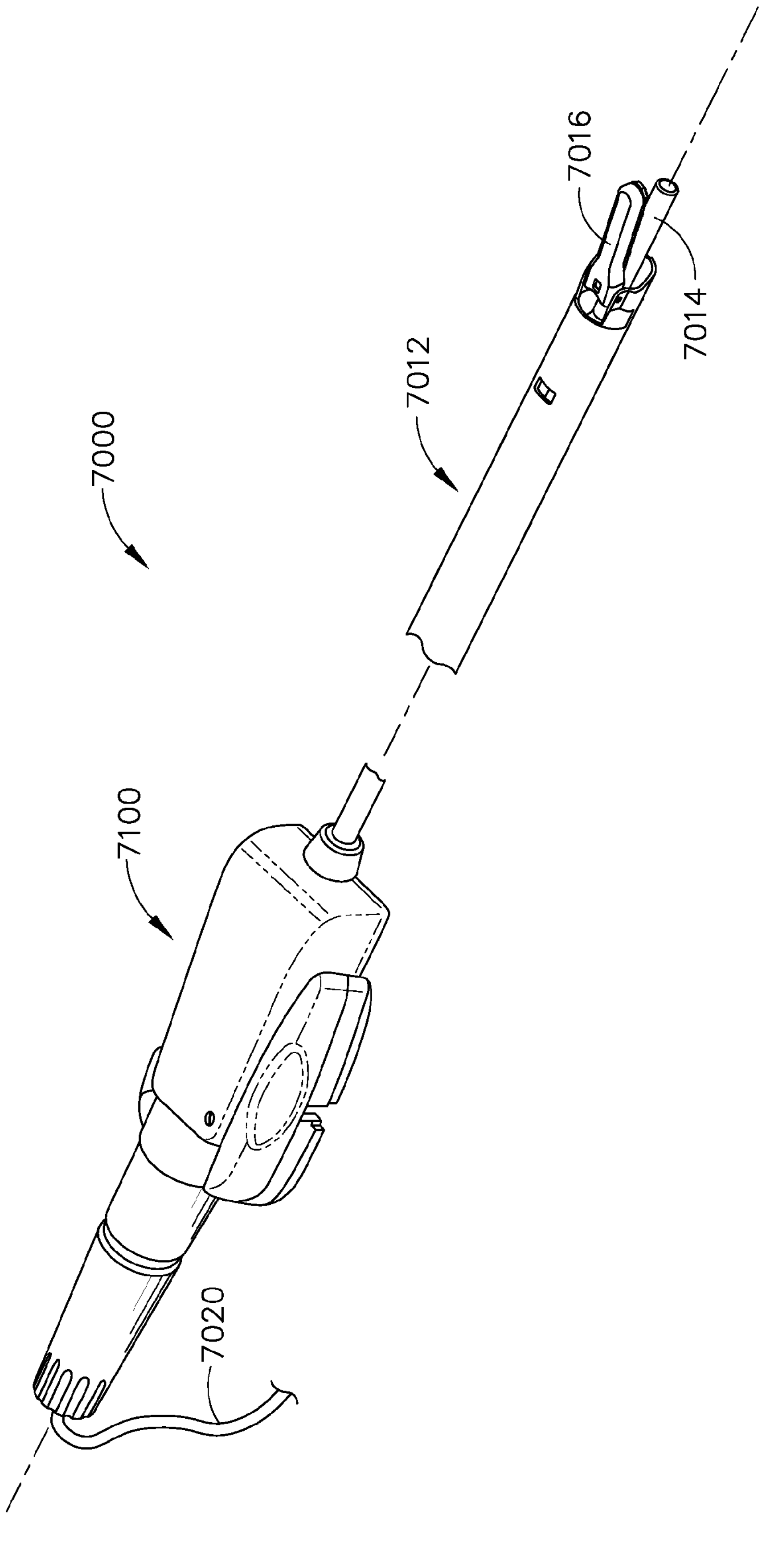

FIG. 141

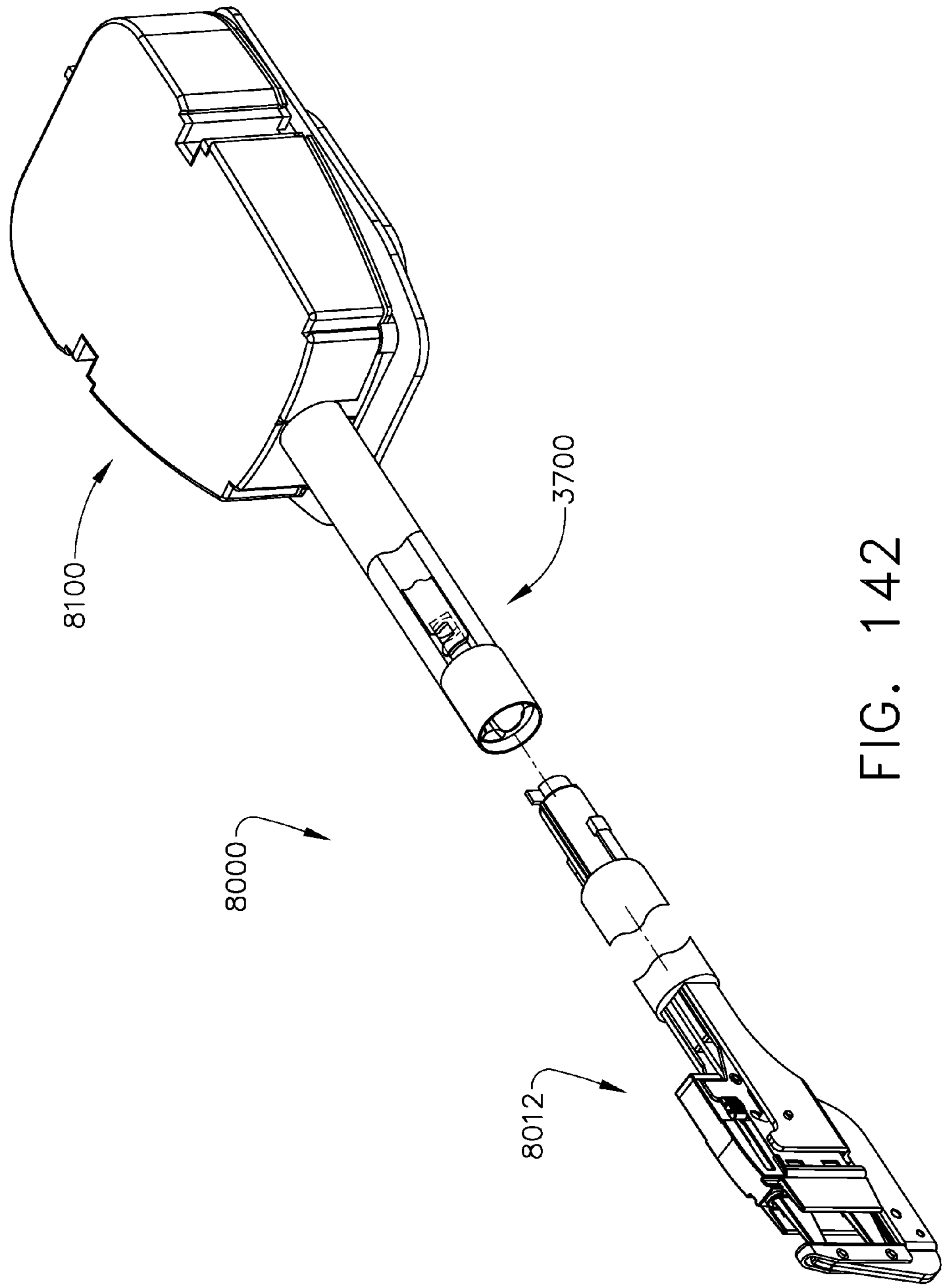

FIG. 142

ROBOTICALLY-CONTROLLED MOTORIZED SURGICAL INSTRUMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

This non-provisional patent application is a continuation-in-part patent application of and claims the benefit from U.S. patent application Ser. No. 12/235,972, filed Sep. 23, 2008, entitled "Motorized Surgical Instrument" to David C. Yates, Thomas W. Huitema, Frederick E. Shelton, IV, and Brett E. Swensgard, U.S. Patent Publication No. US-2010/0076475-A1, the entire disclosure of which is herein incorporated by reference.

BACKGROUND

Surgical staplers have been used in the prior art to simultaneously make a longitudinal incision in tissue and apply lines of staples on opposing sides of the incision. Such instruments commonly include a pair of cooperating jaw members that, if the instrument is intended for endoscopic or laparoscopic applications, are capable of passing through a cannula passageway. One of the jaw members receives a staple cartridge having at least two laterally spaced rows of staples. The other jaw member defines an anvil having staple-forming pockets aligned with the rows of staples in the cartridge. Such instruments typically include a plurality of reciprocating wedges that, when driven distally, pass through openings in the staple cartridge and engage drivers supporting the staples to effect the firing of the staples toward the anvil.

An example of a surgical stapler suitable for endoscopic applications is described in published U.S. patent application Pub. No. 2004/0232196 A1, entitled, "Surgical stapling instrument having separate distinct closing and firing systems," the disclosure of which is herein incorporated by reference. In use, a clinician is able to close the jaw members of the stapler upon tissue to position the tissue prior to firing. Once the clinician has determined that the jaw members are properly gripping tissue, the clinician can fire the surgical stapler, thereby severing and stapling the tissue. The simultaneous severing and stapling steps avoid complications that may arise when performing such actions sequentially with different surgical tools that respectively only sever or staple.

Motor-powered surgical cutting and fastening instruments, where a motor powers the cutting instrument, are also known in the prior art, such as described in published U.S. application Pub. No. 2007/0175962 A1, entitled "Motor-driven surgical cutting and fastening instrument with tactile position feedback," which is incorporated herein by reference. In this reference, a battery in the handle is used to electrically power the motor.

SUMMARY

In one general aspect, embodiments of the present invention are directed to motorized surgical instruments. The instruments may be endoscopic instruments, such as linear endocutters or circular cutters, or laparoscopic instruments. The instruments may be comprised of staples and/or RF electrodes for fastening tissue clamped in the end effector.

Several embodiments disclosed herein are pertinent to cordless motor-powered instruments. In one embodiment, the instrument comprises a charge accumulator device, separate from the battery, that provides additional power to the electric motor when needed. The charge accumulator device may be initially charged by the battery. Then, it may be taken off-line until such time that the extra power from the charge accumulator device is needed. At that time, the charge accumulator device is connected in series with the battery to provide additional power to the motor.

In another embodiment, the motor may comprise at least two windings. In one mode of operation, the windings are connected in series and in another mode of the operation the windings are connected in parallel. When the windings are connected in series, the motor may have a high-speed low-torque output. When the windings are connected in parallel, the motor may have a low-speed high-torque output. That way, for example, the motor could exhibit both modes of operation, without the instrument having to have multiple motors.

In yet another embodiment, the instrument utilizes a replaceable (possibly rechargeable) battery pack to electrically power the motor. The battery pack may comprise a plurality of battery cells. A first set of the battery cells may be connected in series in the battery pack, and a second set of battery cells may be connected in series in the battery pack, but, within the battery pack, the first set is not connected in series to the second set. Rather, the instrument may comprise a battery cell connected in the handle, for example, that connects the first set in series with the second set when the battery pack is installed or placed in the instrument.

In accordance with another general aspect of various embodiments of the present invention, there is provided a robotically-controlled surgical instrument system. In at least one embodiment, the system comprises an end effector that has a moveable cutting instrument. An electric motor communicates with the end effector for actuating the cutting instrument. The system further comprises a motor control circuit for controlling the motor. In at least one form, the motor control circuit comprises a robotic system that operably communicates with the electric motor for supplying power thereto. The motor control circuit further comprises a charge accumulator device and a switching circuit that communicates with the robotic system and the charge accumulator device for (i) temporarily connecting the charge accumulator device to the robotic system to charge the charge accumulator device, and (ii) selectively connecting the charge accumulator device in series with the robotic system to provide additional power to the motor.

In accordance with still another general aspect of various embodiments of the present invention, there is provided a surgical instrument system that includes a robotic system that has an end effector operably coupled to a portion thereof. The end effector includes a moveable cutting instrument. In at least one form, the system includes an electric motor for actuating the cutting instrument, wherein the motor comprises at least two windings. A motor control circuit is connected to the motor that selectively connects the at least two motor windings in series or in parallel.

In accordance with another general aspect of various embodiments of the present invention, there is provided a surgical instrument system that comprises an end effector that is operably coupled to a robotic system. The end effector includes a moveable cutting instrument. The system further includes an electric motor for actuating the cutting instrument. A removable battery pack is provided within the robotic system for powering the motor, wherein the battery pack comprises a plurality of battery cells. The plurality of battery cells comprise a first plurality of series-connected battery cells and a second plurality of series-connected battery cells. The system further includes a battery cell connector that is separate from the battery pack. The battery cell connector connects in series the first plurality of series-connected battery cells to the second plurality of series-connected battery cells when the battery pack is in communication with the instrument.

These and other benefits of the present invention will be apparent from the description below.

FIGURES

Various embodiments of the present invention are described herein by way of example in conjunction with the following figures, wherein:

FIGS. **1** and **2** are perspective views of a surgical cutting and fastening instrument according to various embodiments of the present invention;

FIGS. **3-5** are exploded views of an end effector and shaft of the instrument according to various embodiments of the present invention;

FIG. **6** is a side view of the end effector according to various embodiments of the present invention;

FIG. **7** is an exploded view of the handle of the instrument according to various embodiments of the present invention;

FIGS. **8** and **9** are partial perspective views of the handle according to various embodiments of the present invention;

FIG. **10** is a side view of the handle according to various embodiments of the present invention;

FIG. **11** is a schematic diagram of a circuit used in the instrument according to various embodiments of the present invention;

FIGS. **12-14** and **17** are schematic diagrams of circuits used to power the motor of the instrument according to various embodiments of the present invention;

FIG. **15** is a block diagram illustrating a charge management circuit according to various embodiments of the present invention;

FIG. **16** is a block diagram illustrating a charger base according to various embodiments of the present invention;

FIG. **18** illustrates a typical power curve of a battery;

FIGS. **19** and **20** are schematic diagrams of circuits used in the instrument according to various embodiments of the present invention;

FIGS. **21** and **23** are diagrams of instruments according to various embodiments of the present invention;

FIGS. **22** and **24** are diagrams of battery packs according to various embodiments of the present invention;

FIG. **25** is a perspective view of one robotic controller embodiment;

FIG. **26** is a perspective view of one robotic surgical arm cart/manipulator of a robotic system operably supporting a plurality of surgical tool embodiments of the present invention;

FIG. **27** is a side view of the robotic surgical arm cart/manipulator depicted in FIG. **26**;

FIG. **28** is a perspective view of an exemplary cart structure with positioning linkages for operably supporting robotic manipulators that may be used with various surgical tool embodiments of the present invention;

FIG. **29** is a perspective view of a surgical tool embodiment of the present invention;

FIG. **30** is an exploded assembly view of an adapter and tool holder arrangement for attaching various surgical tool embodiments to a robotic system;

FIG. **31** is a side view of the adapter shown in FIG. **30**;

FIG. **32** is a bottom view of the adapter shown in FIG. **30**;

FIG. **33** is a top view of the adapter of FIGS. **30** and **31**;

FIG. **34** is a partial bottom perspective view of the surgical tool embodiment of FIG. **29**;

FIG. **35** is a partial exploded view of a portion of an articulatable surgical end effector embodiment of the present invention;

FIG. **36** is a perspective view of the surgical tool embodiment of FIG. **34** with the tool mounting housing removed;

FIG. **37** is a rear perspective view of the surgical tool embodiment of FIG. **34** with the tool mounting housing removed;

FIG. **38** is a front perspective view of the surgical tool embodiment of FIG. **34** with the tool mounting housing removed;

FIG. **39** is a partial exploded perspective view of the surgical tool embodiment of FIG. **38**;

FIG. **40** is a partial cross-sectional side view of the surgical tool embodiment of FIG. **34**;

FIG. **41** is an enlarged cross-sectional view of a portion of the surgical tool depicted in FIG. **37**;

FIG. **42** is an exploded perspective view of a portion of the tool mounting portion of the surgical tool embodiment depicted in FIG. **34**;

FIG. **43** is an enlarged exploded perspective view of a portion of the tool mounting portion of FIG. **42**;

FIG. **44** is a partial cross-sectional view of a portion of the elongated shaft assembly of the surgical tool of FIG. **34**;

FIG. **45** is a side view of a half portion of a closure nut embodiment of a surgical tool embodiment of the present invention;

FIG. **46** is a perspective view of another surgical tool embodiment of the present invention;

FIG. **47** is a cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. **46** with the anvil in the open position and the closure clutch assembly in a neutral position;

FIG. **48** is another cross-sectional side view of the surgical end effector and elongated shaft assembly shown in FIG. **47** with the clutch assembly engaged in a closure position;

FIG. **49** is another cross-sectional side view of the surgical end effector and elongated shaft assembly shown in FIG. **47** with the clutch assembly engaged in a firing position;

FIG. **50** is a top view of a portion of a tool mounting portion embodiment of the present invention;

FIG. **51** is a perspective view of another surgical tool embodiment of the present invention;

FIG. **52** is a cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. **51** with the anvil in the open position;

FIG. **53** is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. **51** with the anvil in the closed position;

FIG. **54** is a perspective view of a closure drive nut and portion of a knife bar embodiment of the present invention;

FIG. **55** is a top view of another tool mounting portion embodiment of the present invention;

FIG. **56** is a perspective view of another surgical tool embodiment of the present invention;

FIG. **57** is a cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. **56** with the anvil in the open position;

FIG. **58** is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. **57** with the anvil in the closed position;

FIG. **59** is a cross-sectional view of a mounting collar embodiment of a surgical tool embodiment of the present invention showing the knife bar and distal end portion of the closure drive shaft;

FIG. **60** is a cross-sectional view of the mounting collar embodiment of FIG. **59**;

FIG. **61** is a top view of another tool mounting portion embodiment of another surgical tool embodiment of the present invention;

FIG. **61**A is an exploded perspective view of a portion of a gear arrangement of another surgical tool embodiment of the present invention;

FIG. **61**B is a cross-sectional perspective view of the gear arrangement shown in FIG. **61**A;

FIG. **62** is a cross-sectional side view of a portion of a surgical end effector and elongated shaft assembly of another surgical tool embodiment of the present invention employing a pressure sensor arrangement with the anvil in the open position;

FIG. **63** is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. **62** with the anvil in the closed position;

FIG. **64** is a side view of a portion of another surgical tool embodiment of the present invention in relation to a tool holder portion of a robotic system with some of the components thereof shown in cross-section;

FIG. **65** is a side view of a portion of another surgical tool embodiment of the present invention in relation to a tool holder portion of a robotic system with some of the components thereof shown in cross-section;

FIG. **66** is a side view of a portion of another surgical tool embodiment of the present invention with some of the components thereof shown in cross-section;

FIG. **67** is a side view of a portion of another surgical end effector embodiment of a portion of a surgical tool embodiment of the present invention with some components thereof shown in cross-section;

FIG. **68** is a side view of a portion of another surgical end effector embodiment of a portion of a surgical tool embodiment of the present invention with some components thereof shown in cross-section;

FIG. **69** is a side view of a portion of another surgical end effector embodiment of a portion of a surgical tool embodiment of the present invention with some components thereof shown in cross-section;

FIG. **70** is an enlarged cross-sectional view of a portion of the end effector of FIG. **69**;

FIG. **71** is another cross-sectional view of a portion of the end effector of FIGS. **69** and **70**;

FIG. **72** is a cross-sectional side view of a portion of a surgical end effector and elongated shaft assembly of another surgical tool embodiment of the present invention with the anvil in the open position;

FIG. **73** is an enlarged cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. **72**;

FIG. **74** is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of FIGS. **72** and **73** with the anvil thereof in the closed position;

FIG. **75** is an enlarged cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIGS. **72-74**;

FIG. **76** is a top view of a tool mounting portion embodiment of a surgical tool embodiment of the present invention;

FIG. **77** is a perspective assembly view of another surgical tool embodiment of the present invention;

FIG. **78** is a front perspective view of a disposable loading unit arrangement that may be employed with various surgical tool embodiments of the present invention;

FIG. **79** is a rear perspective view of the disposable loading unit of FIG. **78**;

FIG. **80** is a bottom perspective view of the disposable loading unit of FIGS. **78** and **79**;

FIG. **81** is a bottom perspective view of another disposable loading unit embodiment that may be employed with various surgical tool embodiments of the present invention;

FIG. **82** is an exploded perspective view of a mounting portion of a disposable loading unit depicted in FIGS. **78-80**;

FIG. **83** is a perspective view of a portion of a disposable loading unit and an elongated shaft assembly embodiment of a surgical tool embodiment of the present invention with the disposable loading unit in a first position;

FIG. **84** is another perspective view of a portion of the disposable loading unit and elongated shaft assembly of FIG. **83** with the disposable loading unit in a second position;

FIG. **85** is a cross-sectional view of a portion of the disposable loading unit and elongated shaft assembly embodiment depicted in FIGS. **83** and **84**;

FIG. **86** is another cross-sectional view of the disposable loading unit and elongated shaft assembly embodiment depicted in FIGS. **83-85**;

FIG. **87** is a partial exploded perspective view of a portion of another disposable loading unit embodiment and an elongated shaft assembly embodiment of a surgical tool embodiment of the present invention;

FIG. **88** is a partial exploded perspective view of a portion of another disposable loading unit embodiment and an elongated shaft assembly embodiment of a surgical tool embodiment of the present invention;

FIG. **89** is another partial exploded perspective view of the disposable loading unit embodiment and an elongated shaft assembly embodiment of FIG. **88**;

FIG. **90** is a top view of another tool mounting portion embodiment of a surgical tool embodiment of the present invention;

FIG. **91** is a side view of another surgical tool embodiment of the present invention with some of the components thereof shown in cross-section and in relation to a robotic tool holder of a robotic system;

FIG. **92** is an exploded assembly view of a surgical end effector embodiment that may be used in connection with various surgical tool embodiments of the present invention;

FIG. **93** is a side view of a portion of a cable-driven system for driving a cutting instrument employed in various surgical end effector embodiments of the present invention;

FIG. **94** is a top view of the cable-driven system and cutting instrument of FIG. **93**;

FIG. **95** is a top view of a cable drive transmission embodiment of the present invention in a closure position;

FIG. **96** is another top view of the cable drive transmission embodiment of FIG. **95** in a neutral position;

FIG. **97** is another top view of the cable drive transmission embodiment of FIGS. **95** and **96** in a firing position;

FIG. **98** is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. **95**;

FIG. **99** is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. **96**;

FIG. **100** is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. **97**;

FIG. **101** is a perspective view of another surgical tool embodiment of the present invention;

FIG. **102** is a side view of a portion of another cable-driven system embodiment for driving a cutting instrument employed in various surgical end effector embodiments of the present invention;

FIG. **103** is a top view of the cable-driven system embodiment of FIG. **102**;

FIG. **104** is a top view of a tool mounting portion embodiment of another surgical tool embodiment of the present invention;

FIG. **105** is a top cross-sectional view of another surgical tool embodiment of the present invention;

FIG. **106** is a cross-sectional view of a portion of a surgical end effector embodiment of a surgical tool embodiment of the present invention;

FIG. **107** is a cross-sectional end view of the surgical end effector of FIG. **106** taken along line **107-107** in FIG. **106**;

FIG. **108** is a perspective view of the surgical end effector of FIGS. **106** and **107** with portions thereof shown in cross-section;

FIG. **109** is a side view of a portion of the surgical end effector of FIGS. **106-108**;

FIG. **110** is a perspective view of a sled assembly embodiment of various surgical tool embodiments of the present invention;

FIG. **111** is a cross-sectional view of the sled assembly embodiment of FIG. **110** and a portion of the elongated channel of FIG. **109**;

FIGS. **112-117** diagrammatically depict the sequential firing of staples in a surgical tool embodiment of the present invention;

FIG. **118** is a partial perspective view of a portion of a surgical end effector embodiment of the present invention;

FIG. **119** is a partial cross-sectional perspective view of a portion of a surgical end effector embodiment of a surgical tool embodiment of the present invention;

FIG. **120** is another partial cross-sectional perspective view of the surgical end effector embodiment of FIG. **119** with a sled assembly axially advancing therethrough;

FIG. **121** is a perspective view of another sled assembly embodiment of another surgical tool embodiment of the present invention;

FIG. **122** is a partial top view of a portion of the surgical end effector embodiment depicted in FIGS. **119** and **120** with the sled assembly axially advancing therethrough;

FIG. **123** is another partial top view of the surgical end effector embodiment of FIG. **122** with the top surface of the surgical staple cartridge omitted for clarity;

FIG. **124** is a partial cross-sectional side view of a rotary driver embodiment and staple pusher embodiment of the surgical end effector depicted in FIGS. **119** and **120**;

FIG. **125** is a perspective view of an automated reloading system embodiment of the present invention with a surgical end effector in extractive engagement with the extraction system thereof;

FIG. **126** is another perspective view of the automated reloading system embodiment depicted in FIG. **125**;

FIG. **127** is a cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. **125** and **126**;

FIG. **128** is another cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. **125-127** with the extraction system thereof removing a spent surgical staple cartridge from the surgical end effector;

FIG. **129** is another cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. **125-127** illustrating the loading of a new surgical staple cartridge into a surgical end effector;

FIG. **130** is a perspective view of another automated reloading system embodiment of the present invention with some components shown in cross-section;

FIG. **131** is an exploded perspective view of a portion of the automated reloading system embodiment of FIG. **130**;

FIG. **132** is another exploded perspective view of the portion of the automated reloading system embodiment depicted in FIG. **131**;

FIG. **133** is a cross-sectional elevational view of the automated reloading system embodiment of FIGS. **130-132**;

FIG. **134** is a cross-sectional view of an orientation tube embodiment supporting a disposable loading unit therein;

FIG. **135** is a perspective view of another surgical tool embodiment of the present invention;

FIG. **136** is a partial perspective view of an articulation joint embodiment of a surgical tool embodiment of the present invention;

FIG. **137** is a perspective view of a closure tube embodiment of a surgical tool embodiment of the present invention;

FIG. **138** is a perspective view of the closure tube embodiment of FIG. **137** assembled on the articulation joint embodiment of FIG. **136**;

FIG. **139** is a top view of a portion of a tool mounting portion embodiment of a surgical tool embodiment of the present invention;

FIG. **140** is a perspective view of an articulation drive assembly embodiment employed in the tool mounting portion embodiment of FIG. **139**;

FIG. **141** is a perspective view of another surgical tool embodiment of the present invention; and

FIG. **142** is a perspective view of another surgical tool embodiment of the present invention.

DETAILED DESCRIPTION

Applicant of the present application also owns the following patent applications that have been filed on even date herewith and which are each herein incorporated by reference in their respective entireties:

- U.S. patent application Ser. No. 13/118,259, now U.S. Patent Application Publication No. 2011/0295270, entitled "Surgical Instrument With Wireless Communication Between a Control Unit of a Robotic System and Remote Sensor";
- U.S. patent application Ser. No. 13/118,210, now U.S. Patent Application Publication No. 2011/0290855, entitled "Robotically-Controlled Disposable Motor Driven Loading Unit";
- U.S. patent application Ser. No. 13/118,194, now U.S. Patent Application Publication No. 2011/0295242, entitled "Robotically-Controlled Endoscopic Accessory Channel";
- U.S. patent application Ser. No. 13/118,278, now U.S. Patent Application Publication No. 2011/0290851, entitled "Robotically-Controlled Surgical Stapling Devices That Produce Formed Staples Having Different Lengths";
- U.S. patent application Ser. No. 13/118,190, now U.S. Patent Application Publication No. 2011/0288573, entitled "Robotically-Controlled Motorized Cutting and Fastening Instrument";
- U.S. patent application Ser. No. 13/118,223, now U.S. Patent Application Publication No. 2011/0290854, entitled "Robotically-Controlled Shaft Based Rotary Drive Systems For Surgical Instruments";
- U.S. patent application Ser. No. 13/118,263, now U.S. Patent Application Publication No. 2011/0295295,

entitled "Robotically-Controlled Surgical Instrument Having Recording Capabilities";

U.S. patent application Ser. No. 13/118,272, now U.S. Patent Application Publication No. 2011/0290856, entitled "Robotically-Controlled Surgical Instrument With Force Feedback Capabilities",

U.S. patent application Ser. No. 13/118,246, now U.S. Patent Application Publication No. 2011/0290853, entitled "Robotically-Driven Surgical Instrument With E-Beam Driver"; and

U.S. patent application Ser. No. 13/118,241, now U.S. Patent Application Publication No. 2012/0298719, entitled "Surgical Stapling Instruments With Rotatable Staple Deployment Arrangements".

Certain exemplary embodiments will now be described to provide an overall understanding of the principles of the structure, function, manufacture, and use of the devices and methods disclosed herein. One or more examples of these embodiments are illustrated in the accompanying drawings. Those of ordinary skill in the art will understand that the devices and methods specifically described herein and illustrated in the accompanying drawings are non-limiting exemplary embodiments and that the scope of the various embodiments of the present invention is defined solely by the claims. The features illustrated or described in connection with one exemplary embodiment may be combined with the features of other embodiments. Such modifications and variations are intended to be included within the scope of the present invention.

Uses of the phrases "in various embodiments," "in some embodiments," "in one embodiment", or "in an embodiment", or the like, throughout the specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics of one or more embodiments may be combined in any suitable manner in one or more other embodiments. Such modifications and variations are intended to be included within the scope of the present invention.

FIGS. **1** and **2** depict a surgical cutting and fastening instrument **10** according to various embodiments of the present invention. The illustrated embodiment is an endoscopic instrument and, in general, the embodiments of the instrument **10** described herein are endoscopic surgical cutting and fastening instruments. It should be noted, however, that according to other embodiments of the present invention, the instrument may be a non-endoscopic surgical cutting and fastening instrument, such as a laparoscopic instrument.

The surgical instrument **10** depicted in FIGS. **1** and **2** comprises a handle **6**, a shaft **8**, and an articulating end effector **12** pivotally connected to the shaft **8** at an articulation pivot **14**. An articulation control **16** may be provided adjacent to the handle **6** to effect rotation of the end effector **12** about the articulation pivot **14**. In the illustrated embodiment, the end effector **12** is configured to act as an endocutter for clamping, severing and stapling tissue, although, in other embodiments, different types of end effectors may be used, such as end effectors for other types of surgical devices, such as graspers, cutters, staplers, clip appliers, access devices, drug/gene therapy devices, ultrasound, RF or laser devices, etc. More details regarding RF devices may be found in the '312 Patent.

The handle **6** of the instrument **10** may include a closure trigger **18** and a firing trigger **20** for actuating the end effector **12**. It will be appreciated that instruments having end effectors directed to different surgical tasks may have different numbers or types of triggers or other suitable controls for operating the end effector **12**. The end effector **12** is shown separated from the handle **6** by a preferably elongate shaft **8**. In one embodiment, a clinician or operator of the instrument **10** may articulate the end effector **12** relative to the shaft **8** by utilizing the articulation control **16**, as described in more detail in published U.S. patent application Pub. No. 2007/0158385 A1, entitled "Surgical Instrument Having An Articulating End Effector," by Geoffrey C. Hueil et al., which is incorporated herein by reference.

The end effector **12** includes in this example, among other things, a staple channel **22** and a pivotally translatable clamping member, such as an anvil **24**, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the end effector **12**. The handle **6** includes a pistol grip **26** towards which a closure trigger **18** is pivotally drawn by the clinician to cause clamping or closing of the anvil **24** toward the staple channel **22** of the end effector **12** to thereby clamp tissue positioned between the anvil **24** and channel **22**. The firing trigger **20** is farther outboard of the closure trigger **18**. Once the closure trigger **18** is locked in the closure position as further described below, the firing trigger **20** may rotate slightly toward the pistol grip **26** so that it can be reached by the operator using one hand. Then the operator may pivotally draw the firing trigger **20** toward the pistol grip **12** to cause the stapling and severing of clamped tissue in the end effector **12**. In other embodiments, different types of clamping members besides the anvil **24** could be used, such as, for example, an opposing jaw, etc.

It will be appreciated that the terms "proximal" and "distal" are used herein with reference to a clinician gripping the handle **6** of an instrument **10**. Thus, the end effector **12** is distal with respect to the more proximal handle **6**. It will be further appreciated that, for convenience and clarity, spatial terms such as "vertical" and "horizontal" are used herein with respect to the drawings. However, surgical instruments are used in many orientations and positions, and these terms are not intended to be limiting and absolute.

The closure trigger **18** may be actuated first. Once the clinician is satisfied with the positioning of the end effector **12**, the clinician may draw back the closure trigger **18** to its fully closed, locked position proximate to the pistol grip **26**. The firing trigger **20** may then be actuated. The firing trigger **20** returns to the open position (shown in FIGS. **1** and **2**) when the clinician removes pressure, as described more fully below. A release button on the handle **6**, when depressed may release the locked closure trigger **18**. The release button may be implemented in various forms such as, for example, as a slide release button **160** shown in FIG. **7** or any of the mechanisms described in published U.S. patent application Pub. No. 2007/0175955 A1, which is incorporated herein by reference.

FIG. **3** is an exploded view of the end effector **12** according to various embodiments. As shown in the illustrated embodiment, the end effector **12** may include, in addition to the previously mentioned channel **22** and anvil **24**, a cutting instrument **32**, a sled **33**, a staple cartridge **34** that is removably seated in the channel **22**, and a helical screw shaft **36**. The cutting instrument **32** may be, for example, a knife. The anvil **24** may be pivotably opened and closed at a pivot point **25** connected to the proximate end of the channel **22**. The anvil **24** may also include a tab **27** at its proximate end that is inserted into a component of the mechanical closure system (described further below) to open and close the anvil **24**. When the closure trigger **18** is actuated, that is, drawn in by a user of the instrument **10**, the anvil **24** may pivot about the pivot point **25** into the clamped or closed position. If clamping of the end effector **12** is satisfactory, the operator may actuate the firing trigger **20**, which, as explained in more detail below, causes the knife **32** and sled **33** to travel longitudinally along the channel **22**, thereby cutting tissue clamped within the end effector **12**. The movement of the sled **33** along the channel **22** causes the staples of the staple cartridge **34** to be driven through the severed tissue and against the closed anvil **24**, which turns the staples to fasten the severed tissue. In various embodiments, the sled **33** may be an integral component of the cartridge **34**. U.S. Pat. No. 6,978,921, entitled "Surgical stapling instrument incorporating an E-beam firing mechanism," which is incorporated herein by reference, provides more details about such two-stroke cutting and fastening instruments. The sled **33** may be part of the cartridge **34**, such that when the knife **32** retracts following the cutting operation, the sled **33** does not retract.

It should be noted that although the embodiments of the instrument **10** described herein employ an end effector **12** that staples the severed tissue, in other embodiments different techniques for fastening or sealing the severed tissue may be used. For example, end effectors that use RF energy or adhesives to fasten the severed tissue may also be used. U.S. Pat. No. 5,709,680 entitled "Electrosurgical Hemostatic Device" to Yates et al., and U.S. Pat. No. 5,688,270 entitled "Electrosurgical Hemostatic Device with Recessed and/or Offset Electrodes" to Yates et al., which are incorporated herein by reference, disclose an endoscopic cutting instrument that uses RF energy to seal the severed tissue. Published U.S. patent application Pub. No. 2007/0102453 A1 to Jerome R. Morgan, et al. and published U.S. patent application Pub. No. 2007/0102452 A1 to Frederick E. Shelton, IV, et al., which are also incorporated herein by reference, disclose endoscopic cutting instruments that use adhesives to fasten the severed tissue. Accordingly, although the description herein refers to cutting/stapling operations and the like below, it should be recognized that this is an exemplary embodiment and is not meant to be limiting. Other tissue-fastening techniques may also be used.

FIGS. **4** and **5** are exploded views and FIG. **6** is a side view of the end effector **12** and shaft **8** according to various embodiments. As shown in the illustrated embodiment, the shaft **8** may include a proximate closure tube **40** and a distal closure tube **42** pivotably linked by a pivot links **44**. The distal closure tube **42** includes an opening **45** into which the tab **27** on the anvil **24** is inserted in order to open and close the anvil **24**, as further described below. Disposed inside the closure tubes **40**, **42** may be a proximate spine tube **46**. Disposed inside the proximate spine tube **46** may be a main rotational (or proximate) drive shaft **48** that communicates with a secondary (or distal) drive shaft **50** via a bevel gear assembly **52**. The secondary drive shaft **50** is connected to a drive gear **54** that engages a proximate drive gear **56** of the helical screw shaft **36**. The vertical bevel gear **52***b* may sit and pivot in an opening **57** in the distal end of the proximate spine tube **46**. A distal spine tube **58** may be used to enclose the secondary drive shaft **50** and the drive gears **54**, **56**. Collectively, the main drive shaft **48**, the secondary drive shaft **50**, and the articulation assembly (e.g., the bevel gear assembly **52***a-c*) are sometimes referred to herein as the "main drive shaft assembly."

A bearing **38**, positioned at a distal end of the staple channel **22**, receives the helical drive screw **36**, allowing the helical drive screw **36** to freely rotate with respect to the channel **22**. The helical screw shaft **36** may interface a threaded opening (not shown) of the knife **32** such that rotation of the shaft **36** causes the knife **32** to translate distally or proximately (depending on the direction of the rotation) through the staple channel **22**. Accordingly, when the main drive shaft **48** is caused to rotate by actuation of the firing trigger **20** (as explained in more detail below), the bevel gear assembly **52***a-c* causes the secondary drive shaft **50** to rotate, which in turn, because of the engagement of the drive gears **54**, **56**, causes the helical screw shaft **36** to rotate, which causes the knife driving member **32** to travel longitudinally along the channel **22** to cut any tissue clamped within the end effector. The sled **33** may be made of, for example, plastic, and may have a sloped distal surface. As the sled **33** traverses the channel **22**, the sloped forward surface may push up or drive the staples in the staple cartridge through the clamped tissue and against the anvil **24**. The anvil **24** turns the staples, thereby stapling the severed tissue. When the knife **32** is retracted, the knife **32** and sled **33** may become disengaged, thereby leaving the sled **33** at the distal end of the channel **22**.

FIGS. **7-10** illustrate an exemplary embodiment of a motor-driven endocutter. The illustrated embodiment provides user-feedback regarding the deployment and loading force of the cutting instrument in the end effector. In addition, the embodiment may use power provided by the user in retracting the firing trigger **20** to power the device (a so-called "power assist" mode). As shown in the illustrated embodiment, the handle **6** includes exterior lower sidepieces **59**, **60** and exterior upper side pieces **61**, **62** that fit together to form, in general, the exterior of the handle **6**. A battery **64**, such as a Li ion battery, may be provided in the pistol grip portion **26** of the handle **6**. The battery **64** powers an electric motor **65** disposed in an upper portion of the pistol grip portion **26** of the handle **6**. According to various embodiments, a number of battery cells connected in series may be used to power the motor **65**.

The motor **65** may be a brushed driving motor having a maximum rotation of approximately 25,000 RPM with no load. In other embodiments, the motor **65** may include a brushless motor, a cordless motor, a synchronous motor, a stepper motor, or any other suitable electric motor. The motor **64** may drive a 90° bevel gear assembly **66** comprising a first bevel gear **68** and a second bevel gear **70**. The bevel gear assembly **66** may drive a planetary gear assembly **72**. The planetary gear assembly **72** may include a pinion gear **74** connected to a drive shaft **76**. The pinion gear **74** may drive a mating ring gear **78** that drives a helical gear drum **80** via a drive shaft **82**. A ring **84** may be threaded on the helical gear drum **80**. Thus, when the motor **65** rotates, the ring **84** is caused to travel along the helical gear drum **80** by means of the interposed bevel gear assembly **66**, planetary gear assembly **72**, and ring gear **78**.

The handle **6** may also include a run motor sensor **110** in communication with the firing trigger **20** to detect when the firing trigger **20** has been drawn in (or "closed") toward the pistol grip portion **26** of the handle **6** by the operator to thereby actuate the cutting/stapling operation by the end effector **12**. The sensor **110** may be a proportional sensor such as, for example, a rheostat, or variable resistor. When the firing trigger **20** is drawn in, the sensor **110** detects the movement, and sends an electrical signal indicative of the voltage (or power) to be supplied to the motor **65**. When the sensor **110** is a variable resistor or the like, the rotation of the motor **65** may be generally proportional to the amount of movement of the firing trigger **20**. That is, if the operator only draws or closes the firing trigger **20** in a little bit, the rotation of the motor **65** is relatively low. When the firing trigger **20** is fully drawn in (or in the fully closed position), the rotation of the motor **65** is at its maximum. In other words, the harder the user pulls on the firing trigger **20**, the more voltage is applied to the motor **65**, causing greater rates of rotation.

The handle **6** may include a middle handle piece **104** adjacent to the upper portion of the firing trigger **20**. The handle **6** also may comprise a bias spring **112** connected between posts on the middle handle piece **104** and the firing trigger **20**. The bias spring **112** may bias the firing trigger **20** to its fully open position. In that way, when the operator releases the firing trigger **20**, the bias spring **112** will pull the firing trigger **20** to its open position, thereby removing actuation of the sensor **110**, thereby stopping rotation of the motor **65**. Moreover, by virtue of the bias spring **112**, any time a user closes the firing trigger **20**, the user will experience resistance to the closing operation, thereby providing the user with feedback as to the amount of rotation exerted by the motor **65**. Further, the operator could stop retracting the firing trigger **20** to remove thereby force from the sensor **100**, to thereby stop the motor **65**. As such, the user may stop the deployment of the end effector **12**, thereby providing a measure of control of the cutting/fastening operation to the operator.

The distal end of the helical gear drum **80** includes a distal drive shaft **120** that drives a ring gear **122**, which mates with a pinion gear **124**. The pinion gear **124** is connected to the main drive shaft **48** of the main drive shaft assembly. In that way, rotation of the motor **65** causes the main drive shaft assembly to rotate, which causes actuation of the end effector **12**, as described above.

The ring **84** threaded on the helical gear drum **80** may include a post **86** that is disposed within a slot **88** of a slotted arm **90**. The slotted arm **90** has an opening **92** its opposite end **94** that receives a pivot pin **96** that is connected between the handle exterior side pieces **59**, **60**. The pivot pin **96** is also disposed through an opening **100** in the firing trigger **20** and an opening **102** in the middle handle piece **104**.

In addition, the handle **6** may include a reverse motor (or end-of-stroke sensor) **130** and a stop motor (or beginning-of-stroke) sensor **142**. In various embodiments, the reverse motor sensor **130** may be a limit switch located at the distal end of the helical gear drum **80** such that the ring **84** threaded on the helical gear drum **80** contacts and trips the reverse motor sensor **130** when the ring **84** reaches the distal end of the helical gear drum **80**. The reverse motor sensor **130**, when activated, sends a signal to the motor **65** to reverse its rotation direction, thereby withdrawing the knife **32** of the end effector **12** following the cutting operation. The stop motor sensor **142** may be, for example, a normally closed limit switch. In various embodiments, it may be located at the proximate end of the helical gear drum **80** so that the ring **84** trips the switch **142** when the ring **84** reaches the proximate end of the helical gear drum **80**.

In operation, when an operator of the instrument **10** pulls back the firing trigger **20**, the sensor **110** detects the deployment of the firing trigger **20** and sends a signal to the motor **65** to cause forward rotation of the motor **65** at, for example, a rate proportional to how hard the operator pulls back the firing trigger **20**. The forward rotation of the motor **65** in turn causes the ring gear **78** at the distal end of the planetary gear assembly **72** to rotate, thereby causing the helical gear drum **80** to rotate, causing the ring **84** threaded on the helical gear drum **80** to travel distally along the helical gear drum **80**. The rotation of the helical gear drum **80** also drives the main drive shaft assembly as described above, which in turn causes deployment of the knife **32** in the end effector **12**. That is, the knife **32** and sled **33** are caused to traverse the channel **22** longitudinally, thereby cutting tissue clamped in the end effector **12**. Also, the stapling operation of the end effector **12** is caused to happen in embodiments where a stapling-type end effector is used.

By the time the cutting/stapling operation of the end effector **12** is complete, the ring **84** on the helical gear drum **80** will have reached the distal end of the helical gear drum **80**, thereby causing the reverse motor sensor **130** to be tripped, which sends a signal to the motor **65** to cause the motor **65** to reverse its rotation. This in turn causes the knife **32** to retract, and also causes the ring **84** on the helical gear drum **80** to move back to the proximate end of the helical gear drum **80**.

The middle handle piece **104** includes a backside shoulder **106** that engages the slotted arm **90** as best shown in FIGS. **8** and **9**. The middle handle piece **104** also has a forward motion stop **107** that engages the firing trigger **20**. The movement of the slotted arm **90** is controlled, as explained above, by rotation of the motor **65**. When the slotted arm **90** rotates CCW as the ring **84** travels from the proximate end of the helical gear drum **80** to the distal end, the middle handle piece **104** will be free to rotate CCW. Thus, as the user draws in the firing trigger **20**, the firing trigger **20** will engage the forward motion stop **107** of the middle handle piece **104**, causing the middle handle piece **104** to rotate CCW. Due to the backside shoulder **106** engaging the slotted arm **90**, however, the middle handle piece **104** will only be able to rotate CCW as far as the slotted arm **90** permits. In that way, if the motor **65** should stop rotating for some reason, the slotted arm **90** will stop rotating, and the user will not be able to further draw in the firing trigger **20** because the middle handle piece **104** will not be free to rotate CCW due to the slotted arm **90**.

Components of an exemplary closure system for closing (or clamping) the anvil **24** of the end effector **12** by retracting the closure trigger **18** are also shown in FIGS. **7-10**. In the illustrated embodiment, the closure system includes a yoke **250** connected to the closure trigger **18** by a pin **251** that is inserted through aligned openings in both the closure trigger **18** and the yoke **250**. A pivot pin **252**, about which the closure trigger **18** pivots, is inserted through another opening in the closure trigger **18** which is offset from where the pin **251** is inserted through the closure trigger **18**. Thus, retraction of the closure trigger **18** causes the upper part of the closure trigger **18**, to which the yoke **250** is attached via the pin **251**, to rotate CCW. The distal end of the yoke **250** is connected, via a pin **254**, to a first closure bracket **256**. The first closure bracket **256** connects to a second closure bracket **258**. Collectively, the closure brackets **256**, **258** define an opening in which the proximate end of the proximate closure tube **40** (see FIG. **4**) is seated and held such that longitudinal movement of the closure brackets **256**, **258** causes longitudinal motion by the proximate closure tube **40**. The instrument **10** also includes a closure rod **260** disposed inside the proximate closure tube **40**. The closure rod **260** may include a window **261** into which a post **263** on one of the handle exterior pieces, such as exterior lower sidepiece **59** in the illustrated embodiment, is disposed to fixedly connect the closure rod **260** to the handle **6**. In that way, the proximate closure tube **40** is capable of moving longitudinally relative to the closure rod **260**. The closure rod **260** may also include a distal collar **267** that fits into a cavity **269** in proximate spine tube **46** and is retained therein by a cap **271** (see FIG. **4**).

In operation, when the yoke **250** rotates due to retraction of the closure trigger **18**, the closure brackets **256**, **258** cause the proximate closure tube **40** to move distally (i.e., away from the handle end of the instrument **10**), which causes the distal closure tube **42** to move distally, which causes the anvil **24** to rotate about the pivot point **25** into the clamped or closed position. When the closure trigger **18** is unlocked from the locked position, the proximate closure tube **40** is caused to slide proximately, which causes the distal closure tube **42** to slide proximately, which, by virtue of the tab **27** being inserted in the window **45** of the distal closure tube **42**, causes the anvil **24** to pivot about the pivot point **25** into the open or unclamped position. In that way, by retracting and locking the closure trigger **18**, an operator may clamp tissue between the anvil **24** and channel **22**, and may unclamp the tissue following the cutting/stapling operation by unlocking the closure trigger **20** from the locked position.

Additional configurations for motorized surgical instruments are disclosed in published U.S. application Pub. No. 2007/0175962 A1, entitled "Motor-driven surgical cutting and fastening instrument with tactile position feedback," which is incorporated herein by reference in its entirety.

FIG. **11** is a schematic diagram of the motor control circuit according to various embodiments of the present invention. In various embodiments, the motor control circuit may include one of more integrated circuits (ICs), such as, for example, a processor, memory, microcontroller, time circuits, etc. In other embodiments, the motor control circuit may not comprise any ICs. Such a non-IC motor control circuit may be advantageous because it is often difficult, complicated, and expensive to sterilize a surgical instrument including ICs.

When an operator initially pulls in the firing trigger **20** after locking the closure trigger **18**, the sensor **110** is activated (or closed, where the sensor **110** is a switch), allowing current to flow therethrough. If the normally open reverse motor sensor switch **130** is open (meaning the end of the end effector stroke has not been reached), current will flow to a single pole, double throw relay **132**. When the reverse motor sensor switch **130** is not closed, a coil **134** of the relay **132** will not be energized, so the relay **132** will be in its de-energized state.

As shown in FIG. **11**, the circuit may also include a resistive element **144** and a switch **146** connected in parallel, with the paralleled elements connected in series with the relay **132**. The resistive element **144** and the switch **146** are also connected to the power source **64**. The switch **146** may be controlled by a control circuit **148** that is responsive to the cutting instrument position sensor **150**. According to various embodiments, the control circuit **148** may open the switch **146** when the cutting instrument **32** is (i) very near to the beginning of its stroke and (ii) very near to the end of its stroke. For example, the control circuit may open the switch when the cutting instrument **32** is (i) 0.001 inches from the beginning point of its stroke and (ii) 0.001 inches from the end of its stroke, as determined by the cutting instrument position sensor **150**. With the switch **146** open, current flows through the resistive element **144**, and then through the relay **132**, the relay **138**, the run motor sensor switch **110**, to the motor **65**. Current flowing through the resistive element **144** reduces the magnitude of the current delivered to the motor **65**, thereby reducing the power delivered by the motor **65**. Thus, when the cutting instrument **32** is (i) very near to the beginning of its stroke or (ii) very near to the end of its stroke, the power delivered by the motor **65** is reduced. Conversely, once the cutting instrument **32** moves sufficiently far from its beginning point or end of stroke point, the control circuit **148** may close the switch **146**, thereby shorting the resistive element **144**, thereby increasing the current to the motor **65**, thereby increasing the power delivered by the motor.

According to various embodiments, the electrical circuit further includes lockout sensor switches **136***a-d* collectively defining an interlock circuit **137** through which current from the relay **132**, when de-energized, passes in order for electrical operation of the motor **65** to be initiated. Each lockout sensor switch **136***a-d* may be configured to maintain an open (i.e., non-conductive) switch state or a closed (i.e., conductive) switch state responsive to the presence or absence, respectively, of a corresponding condition. Any of the corresponding conditions, if present when the instrument **10** is fired, may result in an unsatisfactory cutting and stapling operation and/or damage to the instrument **10**. Conditions to which the lockout sensor switches **136***a-d* may respond include, for example, (*a*) the absence of the staple cartridge **34** in the channel **22**, (*b*) the presence of a spent (e.g., previously fired) staple cartridge **34** in the channel **22**, and (*c*) an open (or otherwise insufficiently closed) position of the anvil **24** with respect to the channel **22**. Other conditions to which the lockout sensor switches **136***a-d* may respond, such as component wear, may be inferred based upon an accumulated number of firing operations produced by the instrument **10**. Accordingly, in various embodiments, if any of these conditions exists, the corresponding lockout sensor switches **136***a-d* maintain an open switch state, thus preventing passage of the current necessary to initiate operation of the motor **65**. Passage of current by the lockout sensors **136***a-d* is allowed, in various embodiments, only after all of the conditions have been remedied. It will be appreciated that the above-described conditions are provided by way of example only, and that additional lockout sensor switches for responding to other conditions detrimental to operation of the instrument **10** may be provided. It will similarly be appreciated that for embodiments in which one or more of the above-described conditions may not exist or are of no concern, the number of lockout sensor switches may be fewer than that depicted.

As shown in FIG. **11**, the lockout sensor switch **136***a* may be implemented using a normally open switch configuration such that a closed switch state is maintained when the staple cartridge **34** is in a position corresponding to its proper receipt by the channel **22**. When the staple cartridge **34** is not installed in the channel **22**, or is installed improperly (e.g., misaligned), the lockout sensor switch **136***a* maintains an open switch state. Lockout sensor switch **136***b* may be implemented using a normally open switch configuration such that a closed switch state is maintained only when an unspent staple cartridge **34** (i.e., a staple cartridge **34** having a sled **33** in the unfired position) is present in the channel **22**. The presence of a spent staple cartridge **34** in the channel **22** causes the lockout sensor switch **136***b* to maintain an open switch state. Lockout sensor switch **136***c* may be implemented using a normally open switch configuration such that a closed switch state is maintained when the anvil **24** is in a closed position with respect to the channel **22**. The lockout sensor switch **136***c* may be controlled in accordance with a time delay feature wherein a closed switch state is maintained only after the anvil **24** is in the closed position for a predetermined period of time.

Lockout sensor switch **136***d* may be implemented using a normally closed switch configuration such that a closed switch state is maintained only when an accumulated number of firings produced by the instrument **10** is less than a predetermined number. The lockout sensor switch **136***d* may be in communication with a counter **139** configured for maintaining a count representative of the accumulated number of firing operations performed by the instrument **10**, comparing the count to the pre-determined number, and controlling the switch state of the lockout sensor switch **136***d* based upon the comparison. Although shown separately in FIG. **11**, it will be appreciated that counter **139** may be integral with the lockout sensor switch **136***d* so as to form a common device. Preferably, the counter **139** is implemented as an electronic device having an input for incrementing the maintained count based upon the transition of a discrete electrical signal provided thereto. It will be appreciated that a mechanical counter configured for maintaining the count based upon a mechanical input (e.g., retraction of the firing trigger **20**) may be used instead. When implemented as an electronic device, any discrete signal present in the electrical circuit that transitions once for each firing operation may be utilized for the counter **139** input. As shown in FIG. **11**, for example, the discrete electrical signal resulting from actuation of the end-of-stroke sensor **130** may be utilized. The counter **139** may control the switch state of lockout sensor switch **136***d* such that a closed switch state is maintained when the maintained count is less than a pre-determined number stored within the counter **139**. When the maintained count is equal to the pre-determined number, the counter **139** causes the lockout sensor switch **136***d* to maintain an open switch state, thus preventing the passage of current therethrough. It will be appreciated that the pre-determined number stored by the counter **139** may be selectively adjusted as required. According to various embodiments, the counter **304** may be in communication with an external display (not shown), such as an LCD display, integral to the instrument **10** for indicating to a user either the maintained count or the difference between the pre-determined number and the maintained count.

According to various embodiments, the interlock circuit **137** may comprise one or more indicators visible to the user of the instrument **10** for displaying a status of at least one of the lockout sensor switches **136***a-d*. More details regarding such indicators may be found in published U.S. patent application Pub. No. 2007/0175956, entitled "Electronic lockouts and surgical instrument including same," which is incorporated herein by reference in its entirety. This application also includes example mounting arrangements and configurations for the lockout sensor switches **136***a-d*.

In the illustrated embodiment, when the lockout sensor switches **136***a-d* collectively maintain a closed switch state, a single pole, single throw relay **138** is energized. When the relay **138** is energized, current flows through the relay **138**, through the run motor switch sensor **110**, and to the motor **65** via a double pole, double throw relay **140**, thereby powering the motor **65**, allowing it to rotate in the forward direction. According to various embodiments, because the output of the relay **138**, once energized, maintains the relay **138** in an energized state until relay **132** is energized, the interlock circuit **137** will not function to prevent operation of the motor **165** once initiated, even if one or more of the interlock sensor switches **136***a-d* subsequently maintains an open switch state. In other embodiments, however, it may be necessary or otherwise desirable to connect the interlock circuit **137** and the relay **138** such that one or more the lockout sensor switches **136***a-d* must maintain a closed switch state in order to sustain operation of the motor **165** once initiated.

Rotation of the motor in the forward direction causes the ring **84** to move distally and thereby de-actuate the stop motor sensor switch **142** in various embodiments. Because the switch **142** is normally closed, a solenoid **141** connected to the switch **142** may be energized. The solenoid **141** may be a conventional push-type solenoid that, when energized, causes a plunger (not shown) to be axially extended. Extension of the plunger may operate to retain the closure trigger **18** in the retracted position, thus preventing the anvil **24** from opening while a firing operation is in progress (i.e., while the switch **142** is not actuated). Upon deenergization of the solenoid **141**, the plunger is retracted such that manual release of the closure trigger **18** is possible.

When the end effector **12** reaches the end of its stroke, the reverse motor sensor **130** will be activated, thereby closing the switch **130** and energizing the relay **132**. This causes the relay **132** to assume its energized state (not shown in FIG. **11**), which causes current to bypass the interlock circuit **137** and run motor sensor switch **110**, and instead causes current to flow to both the normally-closed double pole, double throw relay **140** and back to the motor **65**, but in a manner, via the relay **140**, that causes the motor **65** to reverse its rotational direction. Because the stop motor sensor switch **142** is normally closed, current will flow back to the relay **132** to keep it energized until the switch **142** opens. When the knife **32** is fully retracted, the stop motor sensor switch **142** is activated, causing the switch **142** to open, thereby removing power from the motor **65**, and de-energizing the solenoid **141**.

In other embodiments, other alternatives may be used to limit the current supplied to the motor **65** during certain time periods during the cutting stroke cycle. Other embodiments are described in U.S. patent application Ser. No. 12/235,782, which is incorporated herein by reference in its entirety.

In some instances, it may be advantageous to provide a momentary increase in current to the motor **65** to increase the output torque. FIG. **19** shows an embodiment of a circuit for providing a momentary increase to the motor **65** according to various embodiments. The circuit is similar to that shown in FIG. **11**, except that the circuit of FIG. **19** additionally includes a charge accumulator device **1000** connected to the power source **64**. The charge accumulator device **1000** may be any device that can store charge, such as a capacitor. For example, the charge accumulator device **1000** may comprise an ultracapacitor (sometimes called a supercapacitor). When the motor **65** is first turned on, such as when the switch **110** is closed due to retraction of the firing trigger **20**, the switch S**1** may be closed so that the battery **64** can power the motor **65** as described above. In addition, the switch S**3** may also be closed for only a brief period of time ("the charging period") to charge the charge accumulator device **1000** via the resistor R**1**. For example, according to various embodiments, the switch S**3** may be closed for one to ten RC time constants, where R is the resistance of the resistor R**1** and C is the capacitance of the charge accumulator device **1000**.

The charge in the charge accumulator device **1000** may remain unused during normal operating conditions, but if there comes a time in the procedure where the clinician needs additional output torque from the motor **65**, the charge accumulator device **1000** could be put in series with the battery **64**. This could be done, for example, by opening switch S**1** and closing switch S**2** (with S**3** remaining open following the charging period). With switch S**2** closed, the charge accumulator device **1000** would be connected in series with the battery **64**, thereby supplying additional current to the motor **65**.

The condition requiring the charge accumulator device **1000** may be detected in numerous ways. For example, there may be a variable resistor or spring connected to the firing trigger **20**. When the firing trigger is retracted beyond a certain point or with a force above a threshold level, the charge accumulator device **1000** may be connected in series to the battery **64**. Additionally or alternatively, the handle **6** may comprise an external switch (not shown) that the clinician could activate to connect the charge accumulator device **1000** in series with battery **64**.

The charge accumulator device **1000** could be used with or without the current limiting devices described above in connection with FIG. **11**.

At some times during use of the instrument **10**, it may be advantageous to have the motor **65** run at high speed but relatively low torque output. At other times, it may be desirable to have the motor **65** have a high torque output but at low speeds. According to various embodiments, this functionality may be accomplished with a motor **65** having multiple (e.g., two or more) windings, as shown in FIG. **20**. In the illustrated embodiment, the motor has two windings. A first winding **1200** may have winding halves (or portions) **1201** and **1202**. A second winding **1204** may have winding halves (or portions) **1206** and **1208**. The motor **65** in this example may be a 6 or 8 lead motor with a bipolar driving circuit **1210** (see

FIGS. **11** and **12**, for example). When the high-speed low-torque mode is desired, the two sets of winding may be connected in series. In this mode, as shown in FIG. **20**, switches S**1** and S**4** are closed, and switches S**2**, S**3**, S**5**, and S**6** are open. When the low-speed high-torque mode is desired, the two sets of windings may be connected in parallel. In this mode, switches S**1** and S**4** are open, and switches S**2**, S**3**, S**5**, and S**6** are closed. The ability to transition between the two modes effectively creates a two-speed transmission with no additional moving parts. It also allows the same motor to generate both high speeds and high torque outputs, albeit not at the same time. An advantage of this configuration is that it avoids using multiple motors. In addition, it may be possible to eliminate some gearing because the motor **65** can generate extra torque when in the parallel mode and extra speed when in the series mode. In addition, additional windings could be employed such that a greater number of operating modes may be realized. For example, there could be windings for multiple combinations of series and parallel winding connections. Also, some windings may be used for sensing motor conditions, etc.

According to various embodiments, the handle **6** may comprise an external motor mode selection switch **1220**, as shown in FIG. **21**. By using the switch **1220**, the operator of the instrument **10** could select with the motor **65** is in the high-speed low-torque mode or in the low-speed high-torque mode. Other switching circuits could also be used to toggle the motor **65** between the operating modes, such as switching circuits that automatically switch the motor mode based on sensor inputs.

In a motorized surgical instrument, such as one of the motorized endoscopic instruments described above or in a motorized circular cutter instrument, the motor may be powered by a number of battery cells connected in series. Further, it may be desirable in certain circumstances to power the motor with some fraction of the total number of battery cells. For example, as shown in FIG. **12**, the motor **65** may be powered by a power pack **299** comprising six (6) battery cells **310** connected in series. The battery cells **310** may be, for example, 3-volt lithium battery cells, such as CR 123A battery cells, although in other embodiments, different types of battery cells could be used (including battery cells with different voltage levels and/or different chemistries). If six 3-volt battery cells **310** were connected in series to power the motor **65**, the total voltage available to power the motor **65** would be 18 volts. The battery cells **310** may comprise rechargeable or non-rechargeable battery cells.

In such an embodiment, under the heaviest loads, the input voltage to the motor **65** may sag to about nine to ten volts. At this operating condition, the power pack **299** is delivering maximum power to the motor **65**. Accordingly, as shown in FIG. **12**, the circuit may include a switch **312** that selectively allows the motor **65** to be powered by either (1) all of the battery cells **310** or (2) a fraction of the battery cells **310**. As shown in FIG. **12**, by proper selection, the switch **312** may allow the motor **65** to be powered by all six battery cells or four of the battery cells. That way, the switch **312** could be used to power the motor **65** with either 18 volts (when using all six battery cells **310**) or 12 volts (such using four of the second battery cells). In various embodiments, the design choice for the number of battery cells in the fraction that is used to power the motor **65** may be based on the voltage required by the motor **65** when operating at maximum output for the heaviest loads.

The switch **312** may be, for example, an electromechanical switch, such as a micro switch. In other embodiments, the switch **312** may be implemented with a solid-state switch, such as transistor. A second switch **314**, such as a push button switch, may be used to control whether power is applied to the motor **65** at all. Also, a forward/reverse switch **316** may be used to control whether the motor **65** rotates in the forward direction or the reverse direction. The forward/reverse switch **316** may be implemented with a double pole-double throw switch, such as the relay **140** shown in FIG. **11**.

In operation, the user of the instrument **10** could select the desired power level by using some sort of switch control, such as a position-dependent switch (not shown), such as a toggle switch, a mechanical lever switch, or a cam, which controls the position of the switch **312**. Then the user may activate the second switch **314** to connect the selected battery cells **310** to the motor **65**. In addition, the circuit shown in FIG. **12** could be used to power the motor of other types of motorized surgical instruments, such as circular cutters and/or laparoscopic instruments. More details regarding circular cutters may be found in published U.S. patent applications Pub. No. 2006/0047307 A1 and Pub. No. 2007/0262116 A1, which are incorporated herein by reference.

In other embodiments, as shown in FIG. **13**, a primary power source **340**, such as a battery cell, such as a CR2 or CR123A battery cell, may be used to charge a number of secondary accumulator devices **342**. The primary power source **340** may comprise one or a number of series-connected battery cells, which are preferably replaceable in the illustrated embodiment. The secondary accumulator devices **342** may comprise, for example, rechargeable battery cells and/or supercapacitors (also known as “ultracapacitors” or “electrochemical double layer capacitors” (EDLC)). Supercapacitors are electrochemical capacitors that have an unusually high energy density when compared to common electrolytic capacitors, typically on the order of thousands of times greater than a high-capacity electrolytic capacitor.

The primary power source **340** may charge the secondary accumulator devices **342**. Once sufficiently charged, the primary power source **340** may be removed and the secondary accumulator devices **342** may be used to power the motor **65** during a procedure or operation. The accumulating devices **342** may take about fifteen to thirty minutes to charge in various circumstances. Supercapacitors have the characteristic they can charge and discharge extremely rapidly in comparison to conventional batteries. In addition, whereas batteries are good for only a limited number of charge/discharge cycles, supercapacitors can often be charged/discharged repeatedly, sometimes for tens of millions of cycles. For embodiments using supercapacitors as the secondary accumulator devices **342**, the supercapacitors may comprise carbon nanotubes, conductive polymers (e.g., polyacenes), or carbon aerogels.

As shown in FIG. **14**, a charge management circuit **344** could be employed to determine when the secondary accumulator devices **342** are sufficiently charged. The charge management circuit **344** may include an indicator, such as one or more LEDs, an LCD display, etc., that is activated to alert a user of the instrument **10** when the secondary accumulator devices **342** are sufficiently charged.

The primary power source **340**, the secondary accumulator devices **342**, and the charge management circuit **344** may be part of a power pack in the pistol grip portion **26** of the handle **6** of the instrument **10**, or in another part of the instrument **10**. The power pack may be removable from the pistol grip portion **26**, in which case, when the instrument **10** is to be used for surgery, the power pack may be inserted aseptically into the pistol grip portion **26** (or other position in the instrument according to other embodiments) by, for example, a circulating nurse assisting in the surgery. After insertion of the power pack, the nurse could put the replaceable primary power source **340** in the power pack to charge up the secondary accumulator devices **342** a certain time period prior to use of the instrument **10**, such as thirty minutes. When the secondary accumulator devices **342** are charged, the charge management circuit **344** may indicate that the power pack is ready for use. At this point, the replaceable primary power source **340** may be removed. During the operation, the user of the instrument **10** may then activate the motor **65**, such as by activating the switch **314**, whereby the secondary accumulator devices **342** power the motor **65**. Thus, instead of having a number of disposable batteries to power the motor **65**, one disposable battery (as the primary power source **340**) could be used in such an embodiment, and the secondary accumulator devices **342** could be reusable. In alternative embodiments, however, it should be noted that the secondary accumulator devices **342** could be non-rechargeable and/or non-reusable. The secondary accumulators **342** may be used with the cell selection switch **312** described above in connection with FIG. **12**.

The charge management circuit **344** may also include indicators (e.g., LEDs or LCD display) that indicate how much charge remains in the secondary accumulator devices **342**. That way, the surgeon (or other user of the instrument **10**) can see how much charge remains through the course of the procedure involving the instrument **10**.

The charge management circuit **344**, as shown in FIG. **15**, may comprise a charge meter **345** for measuring the charge across the secondary accumulators **342**. The charge management circuit **344** also may comprise a non-volatile memory **346**, such as flash or ROM memory, and one or more processors **348**. The processor(s) **348** may be connected to the memory **346** to control the memory. In addition, the processor(s) **348** may be connected to the charge meter **345** to read the readings of and otherwise control the charge meter **345**. Additionally, the processor(s) **348** may control the LEDs or other output devices of the charge management circuit **344**. The processor(s) **348** can store parameters of the instrument **10** in the memory **346**. The parameters may include operating parameters of the instrument that are sensed by various sensors that may be installed or employed in the instrument **10**, such as, for example, the number of firings, the levels of forces involved, the distance of the compression gap between the opposing jaws of the end effector **12**, the amount of articulation, etc. Additionally, the parameters stored in the memory **346** may comprise ID values for various components of the instrument **10** that the charge management circuit **344** may read and store. The components having such IDs may be replaceable components, such as the staple cartridge **34**. The IDs may be for example, RFIDs that the charge management circuit **344** reads via a RFID transponder **350**. The RFID transponder **350** may read RFIDs from components of the instrument, such as the staple cartridge **34**, that include RFID tags. The ID values may be read, stored in the memory **346**, and compared by the processor **348** to a list of acceptable ID values stored in the memory **346** or another store associated with the charge management circuit, to determine, for example, if the removable/replaceable component associated with the read ID value is authentic and/or proper. According to various embodiments, if the processor **348** determines that the removable/replaceable component associated with the read ID value is not authentic, the charge management circuit **344** may prevent use of the power pack by the instrument **10**, such as by opening a switch (not shown) that would prevent power from the power pack being delivered to the motor **65**. According to various embodiments, various parameters that the processor **348** may evaluate to determine whether the component is authentic and/or proper include: date code; component model/type; manufacturer; regional information; and previous error codes.

The charge management circuit **344** may also comprise an i/o interface **352** for communicating with another device, such as described below. That way, the parameters stored in the memory **346** may be downloaded to another device. The i/o interface **352** may be, for example, a wired or wireless interface.

As mentioned before, the power pack may comprise the secondary accumulators **342**, the charge management circuit **344**, and/or the f/r switch **316**. According to various embodiments, as shown in FIG. **16**, the power pack **299** could be connected to a charger base **362**, which may, among other things, charge the secondary accumulators **342** in the power pack. The charger base **362** could be connected to the power pack **299** by connecting aseptically the charger base **362** to the power pack **299** while the power pack is installed in the instrument **10**. In other embodiments where the power pack is removable, the charger base **362** could be connected to the power pack **299** by removing the power pack **299** from the instrument **10** and connecting it to the charger base **362**. For such embodiments, after the charger base **362** sufficiently charges the secondary accumulators **342**, the power pack **299** may be aseptically installed in the instrument **10**.

As shown in FIG. **16**, the charger base **362** may comprise a power source **364** for charging the secondary accumulators **342**. The power source **364** of the charger base **362** may be, for example, a battery (or a number of series-connected batteries), or an AC/DC converter that converters AC power, such as from electrical power mains, to DC, or any other suitable power source for charging the secondary accumulators **342**. The charger base **362** may also comprise indicator devices, such as LEDs, a LCD display, etc., to show the charge status of the secondary accumulators **342**.

In addition, as shown in FIG. **16**, the charger base **362** may comprise one or more processors **366**, one or more memory units **368**, and i/o interfaces **370**, **372**. Through the first i/o interface **370**, the charger base **362** may communicate with the power pack **299** (via the power pack's i/o interface **352**). That way, for example, data stored in the memory **346** of the power pack **299** may be downloaded to the memory **368** of the charger base **362**. In that way, the processor **366** can evaluate the ID values for the removable/replaceable components, downloaded from the charge management circuit **344**, to determine the authenticity and suitability of the components. The operating parameters downloaded from the charge management circuit **344** may also stored in the memory **368**, and then may then be downloaded to another computer device via the second i/o interface **372** for evaluation and analysis, such as by the hospital system in which the operation involving the instrument **10** is performed, by the office of the surgeon, by the distributor of the instrument, by the manufacturer of the instrument, etc.

The charger base **362** may also comprise a charge meter **374** for measuring the charge across the secondary accumulators **342**. The charge meter **374** may be in communication with the processor(s) **366**, so that the processor(s) **366** can determine in real-time the suitability of the power pack **299** for use to ensure high performance.

In another embodiment, as shown in FIG. **17**, the battery circuit may comprise a power regulator **320** to control the power supplied by the power savers **310** to the motor **65**. The power regulator **320** may also be part of the power pack **299**, or it may be a separate component. As mentioned above, the motor **65** may be a brushed motor. The speed of brushed motors generally is proportional to the applied input voltage.

The power regulator **320** may provide a highly regulated output voltage to the motor **65** so that the motor **65** will operate at a constant (or substantially constant) speed. According to various embodiments, the power regulator **320** may comprise a switch-mode power converter, such as a buck-boost converter, as shown in the example of FIG. **17**. Such a buck-boost converter **320** may comprise a power switch **322**, such as a FET, a rectifier **32**, an inductor **326**, and a capacitor **328**. When the power switch **322** is on, the input voltage source (e.g., the power sources **310**) is directly connected to the inductor **326**, which stores energy in this state. In this state, the capacitor **328** supplies energy to the output load (e.g., the motor **65**). When the power switch **320** is in the off state, the inductor **326** is connected to the output load (e.g., the motor **65**) and the capacitor **328**, so energy is transferred from the inductor **326** to the capacitor **328** and the load **65**. A control circuit **330** may control the power switch **322**. The control circuit **330** may employ digital and/or analog control loops. In addition, in other embodiments, the control circuit **330** may receive control information from a master controller (not shown) via a communication link, such as a serial or parallel digital data bus. The voltage set point for the output of the power regulator **320** may be set, for example, to one-half of the open circuit voltage, at which point the maximum power available from the source is available.

In other embodiments, different power converter topologies may be employed, including linear or switch-mode power converters. Other switch-mode topologies that may be employed include a flyback, forward, buck, boost, and SEPIC. The set point voltage for the power regulator **320** could be changed depending on how many of the battery cells are being used to power the motor **65**. Additionally, the power regulator **320** could be used with the secondary accumulator devices **342** shown in FIG. **13**. Further, the forward-reverse switch **316** could be incorporated into the power regulator **320**, although it is shown separately in FIG. **17**.

Batteries can typically be modeled as an ideal voltage source and a source resistance. For an ideal model, when the source and load resistance are matched, maximum power is transferred to the load. FIG. **18** shows a typical power curve for a battery. When the battery circuit is open, the voltage across the battery is high (at its open circuit value) and the current drawn from the battery is zero. The power delivered from the battery is zero also. As more current is drawn from the battery, the voltage across the battery decreases. The power delivered by the battery is the product of the current and the voltage. The power reaches its peak around at a voltage level that is less than the open circuit voltage. As shown in FIG. **18**, with most battery chemistries there is a sharp drop in the voltage/power at higher current because of the chemistry or positive temperature coefficient (PTC), or because of a battery protection device.

Particularly for embodiments using a battery (or batteries) to power the motor **65** during a procedure, the control circuit **330** can monitor the output voltage and control the set point of the regulator **320** so that the battery operates on the "left" or power-increasing side of the power curve. If the battery reaches the peak power level, the control circuit **330** can change (e.g., lower) the set point of the regulator so that less total power is being demanded from the battery. The motor **65** would then slow down. In this way, the demand from the power pack would rarely if ever exceed the peak available power so that a power-starving situation during a procedure could be avoided.

In addition, according to other embodiments, the power drawn from the battery may be optimized in such a way that the chemical reactions within the battery cells would have time to recover, to thereby optimize the current and power available from the battery. In pulsed loads, batteries typically provide more power at the beginning of the pulse that toward the end of the pulse. This is due to several factors, including: (1) the PTC may be changing its resistance during the pulse; (2) the temperature of the battery may be changing; and (3) the electrochemical reaction rate is changing due to electrolyte at the cathode being depleted and the rate of diffusion of the fresh electrolyte limits the reaction rate. According to various embodiments, the control circuit **330** may control the converter **320** so that it draws a lower current from the battery to allow the battery to recover before it is pulsed again.

As mentioned above, according to various embodiments the battery pack **299** may comprise multiple battery cells **310**. FIG. **22** shows an embodiment with six (6) battery cells **310**. The battery cells **310** may be, for example, lithium primary batteries. According to various embodiments, the battery pack **299** may have only a fraction of the battery cells internally connected. For example, as shown in FIG. **22**, cell **310*a*** is connected to cell **310*b***, cell **310*c*** is connected to cell **310*d***, and cell **310*e*** is connected to cell **310*f***. However, cell **310*b*** is not connected internally in the battery pack to cell **310*c***, and cell **310*d*** is not connected internally in the battery pack to cell **310*e***. The handle **6** of the instrument **10** in such embodiments may comprise a battery cell connector **1300** that connects the cells **310** in series only when the battery pack **299** is physically inserted in the instrument **10**. For example, the connector **1300** may comprise a positive output terminal **1302**, a connector **1304** that series connects cell **310*b*** to cell **310*c***, a connector **1306** that connects cell **310*d*** to cell **310*e***, and a negative output terminal **1308**.

FIG. **23** shows an embodiment of the instrument **10** where a replaceable, removable battery pack **299** is installed in the handle **6** of the instrument **10**. As shown in FIG. **23**, the battery cell connector **1300** may be integrated into the handle **6** such that, when the battery pack **299** is inserted into the handle **6**, the battery cell connector **1300** makes the necessary battery cell connections.

Of course, in other embodiments, battery packs with a different number of internal cells and different numbers of internally connected cells may be used. For example, FIG. **24** shows an embodiment with six cells **310*a-f***, where two sets of three cells (cells **310*a-c*** and cells **310*d-f***) are connected together.

The devices disclosed herein can be designed to be disposed of after a single use, or they can be designed to be used multiple times. In either case, however, the device can be reconditioned for reuse after at least one use. Reconditioning can include any combination of the steps of disassembly of the device, followed by cleaning or replacement of particular pieces, and subsequent reassembly. In particular, the device can be disassembled, and any number of the particular pieces or parts of the device can be selectively replaced or removed in any combination. Upon cleaning and/or replacement of particular parts, the device can be reassembled for subsequent use either at a reconditioning facility, or by a surgical team immediately prior to a surgical procedure. Those skilled in the art will appreciate that reconditioning of a device can utilize a variety of techniques for disassembly, cleaning/replacement, and reassembly. Use of such techniques, and the resulting reconditioned device, are all within the scope of the present application.

Preferably, the various embodiments of the invention described herein will be processed before surgery. First, a new or used instrument is obtained and if necessary cleaned. The instrument can then be sterilized. In one sterilization technique, the instrument is placed in a closed and sealed container, such as a thermoformed plastic shell covered with a sheet of TYVEK. The container and instrument are then placed in a field of radiation that can penetrate the container, such as gamma radiation, x-rays, or high-energy electrons. The radiation kills bacteria on the instrument and in the container. The sterilized instrument can then be stored in the sterile container. The sealed container keeps the instrument sterile until it is opened in the medical facility.

It is preferred that the device is sterilized. This can be done by any number of ways known to those skilled in the art including beta or gamma radiation, ethylene oxide, steam and other methods.

While the present invention has been illustrated by description of several embodiments and while the illustrative embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications may readily appear to those skilled in the art. The various embodiments of the present invention represent vast improvements over prior staple methods that require the use of different sizes of staples in a single cartridge to achieve staples that have differing formed (final) heights.

Accordingly, the present invention has been discussed in terms of endoscopic procedures and apparatus. However, use herein of terms such as "endoscopic" should not be construed to limit the present invention to a surgical stapling and severing instrument for use only in conjunction with an endoscopic tube (i.e., trocar). On the contrary, it is believed that the present invention may find use in any procedure where access is limited, including but not limited to laparoscopic procedures, as well as open procedures. Moreover, the unique and novel aspects of the various staple cartridge embodiments of the present invention may find utility when used in connection with other forms of stapling apparatuses without departing from the spirit and scope of the present invention.

Over the years a variety of minimally invasive robotic (or "telesurgical") systems have been developed to increase surgical dexterity as well as to permit a surgeon to operate on a patient in an intuitive manner. Many of such systems are disclosed in the following U.S. Patents which are each herein incorporated by reference in their respective entirety: U.S. Pat. No. 5,792,135, entitled "Articulated Surgical Instrument For Performing Minimally Invasive Surgery With Enhanced Dexterity and Sensitivity", U.S. Pat. No. 6,231,565, entitled "Robotic Arm DLUS For Performing Surgical Tasks", U.S. Pat. No. 6,783,524, entitled "Robotic Surgical Tool With Ultrasound Cauterizing and Cutting Instrument", U.S. Pat. No. 6,364,888, entitled "Alignment of Master and Slave In a Minimally Invasive Surgical Apparatus", U.S. Pat. No. 7,524, 320, entitled "Mechanical Actuator Interface System For Robotic Surgical Tools", U.S. Pat. No. 7,691,098, entitled Platform Link Wrist Mechanism", U.S. Pat. No. 7,806,891, entitled "Repositioning and Reorientation of Master/Slave Relationship in Minimally Invasive Telesurgery", and U.S. Pat. No. 7,824,401, entitled "Surgical tool With Writed Monopolar Electrosurgical End Effectors". Many of such systems, however, have in the past been unable to generate the magnitude of forces required to effectively cut and fasten tissue.

FIG. **25** depicts one version of a master controller **1001** that may be used in connection with a robotic arm slave cart **1100** of the type depicted in FIG. **26**. Master controller **1001** and robotic arm slave cart **1100**, as well as their respective components and control systems are collectively referred to herein as a robotic system **1000**. Examples of such systems and devices are disclosed in U.S. Pat. No. 7,524,320 which has been herein incorporated by reference. Thus, various details of such devices will not be described in detail herein beyond that which may be necessary to understand various embodiments and forms of the present invention. As is known, the master controller **1001** generally includes master controllers (generally represented as **1003** in FIG. **25**) which are grasped by the surgeon and manipulated in space while the surgeon views the procedure via a stereo display **1002**. The master controllers **1001** generally comprise manual input devices which preferably move with multiple degrees of freedom, and which often further have an actuatable handle for actuating tools (for example, for closing grasping saws, applying an electrical potential to an electrode, or the like).

As can be seen in FIG. **26**, in one form, the robotic arm cart **1100** is configured to actuate a plurality of surgical tools, generally designated as **1200**. Various robotic surgery systems and methods employing master controller and robotic arm cart arrangements are disclosed in U.S. Pat. No. 6,132, 368, entitled "Multi-Component Telepresence System and Method", the full disclosure of which is incorporated herein by reference. In various forms, the robotic arm cart **1100** includes a base **1002** from which, in the illustrated embodiment, three surgical tools **1200** are supported. In various forms, the surgical tools **1200** are each supported by a series of manually articulatable linkages, generally referred to as set-up joints **1104**, and a robotic manipulator **1106**. These structures are herein illustrated with protective covers extending over much of the robotic linkage. These protective covers may be optional, and may be limited in size or entirely eliminated in some embodiments to minimize the inertia that is encountered by the servo mechanisms used to manipulate such devices, to limit the volume of moving components so as to avoid collisions, and to limit the overall weight of the cart **1100**. Cart **1100** will generally have dimensions suitable for transporting the cart **1100** between operating rooms. The cart **1100** may be configured to typically fit through standard operating room doors and onto standard hospital elevators. In various forms, the cart **1100** would preferably have a weight and include a wheel (or other transportation) system that allows the cart **1100** to be positioned adjacent an operating table by a single attendant.

Referring now to FIG. **27**, in at least one form, robotic manipulators **1106** may include a linkage **1108** that constrains movement of the surgical tool **1200**. In various embodiments, linkage **1108** includes rigid links coupled together by rotational joints in a parallelogram arrangement so that the surgical tool **1200** rotates around a point in space **1110**, as more fully described in issued U.S. Pat. No. 5,817, 084, the full disclosure of which is herein incorporated by reference. The parallelogram arrangement constrains rotation to pivoting about an axis **1112***a*, sometimes called the pitch axis. The links supporting the parallelogram linkage are pivotally mounted to set-up joints **1104** (FIG. **26**) so that the surgical tool **1200** further rotates about an axis **1112***b*, sometimes called the yaw axis. The pitch and yaw axes **1112***a*, **1112***b* intersect at the remote center **1114**, which is aligned along a shaft **1208** of the surgical tool **1200**. The surgical tool **1200** may have further degrees of driven freedom as supported by manipulator **1106**, including sliding motion of the surgical tool **1200** along the longitudinal tool axis "LT-LT". As the surgical tool **1200** slides along the tool axis LT-LT relative to manipulator **1106** (arrow **1112***c*), remote center **1114** remains fixed relative to base **1116** of manipulator **1106**. Hence, the entire manipulator is generally moved to re-position remote center **1114**. Linkage **1108** of manipulator **1106** is driven by a series of motors **1120**. These motors actively move linkage **1108** in response to commands from a processor of a control system. As will be discussed in further detail below, motors **1120** are also employed to manipulate the surgical tool **1200**.

An alternative set-up joint structure is illustrated in FIG. **28**. In this embodiment, a surgical tool **1200** is supported by an alternative manipulator structure **1106'** between two tissue manipulation tools. Those of ordinary skill in the art will appreciate that various embodiments of the present invention may incorporate a wide variety of alternative robotic structures, including those described in U.S. Pat. No. 5,878,193, entitled "Automated Endoscope System For Optimal Positioning", the full disclosure of which is incorporated herein by reference. Additionally, while the data communication between a robotic component and the processor of the robotic surgical system is primarily described herein with reference to communication between the surgical tool **1200** and the master controller **1001**, it should be understood that similar communication may take place between circuitry of a manipulator, a set-up joint, an endoscope or other image capture device, or the like, and the processor of the robotic surgical system for component compatibility verification, component-type identification, component calibration (such as off-set or the like) communication, confirmation of coupling of the component to the robotic surgical system, or the like.

An exemplary non-limiting surgical tool **1200** that is well-adapted for use with a robotic system **1000** that has a tool drive assembly **1010** (FIG. **30**) that is operatively coupled to a master controller **1001** that is operable by inputs from an operator (i.e., a surgeon) is depicted in FIG. **29**. As can be seen in that Figure, the surgical tool **1200** includes a surgical end effector **2012** that comprises an endocutter. In at least one form, the surgical tool **1200** generally includes an elongated shaft assembly **2008** that has a proximal closure tube **2040** and a distal closure tube **2042** that are coupled together by an articulation joint **2011**. The surgical tool **1200** is operably coupled to the manipulator by a tool mounting portion, generally designated as **1300**. The surgical tool **1200** further includes an interface **1230** which mechanically and electrically couples the tool mounting portion **1300** to the manipulator. One form of interface **1230** is illustrated in FIGS. **27-31**. In various embodiments, the tool mounting portion **1300** includes a tool mounting plate **1302** that operably supports a plurality of (four are shown in FIG. **34**) rotatable body portions, driven discs or elements **1304**, that each include a pair of pins **1306** that extend from a surface of the driven element **1304**. One pin **1306** is closer to an axis of rotation of each driven elements **1304** than the other pin **1306** on the same driven element **1304**, which helps to ensure positive angular alignment of the driven element **1304**. Interface **1230** includes an adaptor portion **1240** that is configured to mountingly engage the mounting plate **1302** as will be further discussed below. The adaptor portion **1240** may include an array of electrical connecting pins **1242** (FIG. **32**) which may be coupled to a memory structure by a circuit board within the tool mounting portion **1300**. While interface **1230** is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

As can be seen in FIGS. **30-33**, the adapter portion **1240** generally includes a tool side **1244** and a holder side **1246**. In various forms, a plurality of rotatable bodies **1250** are mounted to a floating plate **1248** which has a limited range of movement relative to the surrounding adaptor structure normal to the major surfaces of the adaptor **1240**. Axial movement of the floating plate **1248** helps decouple the rotatable bodies **1250** from the tool mounting portion **1300** when the levers **1303** along the sides of the tool mounting portion housing **1301** are actuated (See FIG. **29**). Other mechanisms/arrangements may be employed for releasably coupling the tool mounting portion **1300** to the adaptor **1240**. In at least one form, rotatable bodies **1250** are resiliently mounted to floating plate **1248** by resilient radial members which extend into a circumferential indentation about the rotatable bodies **1250**. The rotatable bodies **1250** can move axially relative to plate **1248** by deflection of these resilient structures. When disposed in a first axial position (toward tool side **1244**) the rotatable bodies **1250** are free to rotate without angular limitation. However, as the rotatable bodies **1250** move axially toward tool side **1244**, tabs **1252** (extending radially from the rotatable bodies **1250**) laterally engage detents on the floating plates so as to limit angular rotation of the rotatable bodies **1250** about their axes. This limited rotation can be used to help drivingly engage the rotatable bodies **1250** with drive pins **1272** of a corresponding tool holder portion **1270** of the robotic system **1000**, as the drive pins **1272** will push the rotatable bodies **1250** into the limited rotation position until the pins **1234** are aligned with (and slide into) openings **1256'**. Openings **1256** on the tool side **1244** and openings **1256'** on the holder side **1246** of rotatable bodies **1250** are configured to accurately align the driven elements **1304** (FIG. **34**) of the tool mounting portion **1300** with the drive elements **1271** of the tool holder **1270**. As described above regarding inner and outer pins **1306** of driven elements **1304**, the openings **1256**, **1256'** are at differing distances from the axis of rotation on their respective rotatable bodies **1250** so as to ensure that the alignment is not 180 degrees from its intended position. Additionally, each of the openings **1256** is slightly radially elongated so as to fittingly receive the pins **1306** in the circumferential orientation. This allows the pins **1306** to slide radially within the openings **1256**, **1256'** and accommodate some axial misalignment between the tool **1200** and tool holder **1270**, while minimizing any angular misalignment and backlash between the drive and driven elements. Openings **1256** on the tool side **1244** are offset by about 90 degrees from the openings **1256'** (shown in broken lines) on the holder side **1246**, as can be seen most clearly in FIG. **33**.

Various embodiments may further include an array of electrical connector pins **1242** located on holder side **1246** of adaptor **1240**, and the tool side **1244** of the adaptor **1240** may include slots **1258** (FIG. **33**) for receiving a pin array (not shown) from the tool mounting portion **1300**. In addition to transmitting electrical signals between the surgical tool **1200** and the tool holder **1270**, at least some of these electrical connections may be coupled to an adaptor memory device **1260** (FIG. **32**) by a circuit board of the adaptor **1240**.

A detachable latch arrangement **1239** may be employed to releasably affix the adaptor **1240** to the tool holder **1270**. As used herein, the term "tool drive assembly" when used in the context of the robotic system **1000**, at least encompasses various embodiments of the adapter **1240** and tool holder **1270** and which has been generally designated as **1010** in FIG. **30**. For example, as can be seen in FIG. **30**, the tool holder **1270** may include a first latch pin arrangement **1274** that is sized to be received in corresponding clevis slots **1241** provided in the adaptor **1240**. In addition, the tool holder **1270** may further have second latch pins **1276** that are sized to be retained in corresponding latch devises **1243** in the adaptor **1240**. See FIG. **32**. In at least one form, a latch assembly **1245** is movably supported on the adapter **1240** and is biasable between a first latched position wherein the latch pins **1276** are retained within their respective latch clevis **1243** and an unlatched position wherein the second latch pins **1276** may be into or removed from the latch devises **1243**. A spring or springs (not shown) are employed to bias the latch assembly into the latched position. A lip on the tool side **1244** of adaptor **1240** may slidably receive laterally extending tabs of tool mounting housing **1301**.

Turning next to FIGS. **34-41**, in at least one embodiment, the surgical tool **1200** includes a surgical end effector **2012** that comprises in this example, among other things, at least one component **2024** that is selectively movable between first and second positions relative to at least one other component **2022** in response to various control motions applied thereto as will be discussed in further detail below. In various embodiments, component **2022** comprises an elongated channel **2022** configured to operably support a surgical staple cartridge **2034** therein and component **2024** comprises a pivotally translatable clamping member, such as an anvil **2024**. Various embodiments of the surgical end effector **2012** are configured to maintain the anvil **2024** and elongated channel **2022** at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector **2012**. As can be seen in FIG. **40**, the surgical end effector **2012** further includes a cutting instrument **2032** and a sled **2033**. The cutting instrument **2032** may be, for example, a knife. The surgical staple cartridge **2034** operably houses a plurality of surgical staples (not show) therein that are supported on movable staple drivers (not shown). As the cutting instrument **2032** is driven distally through a centrally-disposed slot (not shown) in the surgical staple cartridge **2034**, it forces the sled **2033** distally as well. As the sled **2033** is driven distally, its "wedge-shaped" configuration contacts the movable staple drivers and drives them vertically toward the closed anvil **2024**. The surgical staples are formed as they are driven into the forming surface located on the underside of the anvil **2024**. The sled **2033** may be part of the surgical staple cartridge **2034**, such that when the cutting instrument **2032** is retracted following the cutting operation, the sled **2033** does not retract. The anvil **2024** may be pivotably opened and closed at a pivot point **2025** located at the proximal end of the elongated channel **2022**. The anvil **2024** may also include a tab **2027** at its proximal end that interacts with a component of the mechanical closure system (described further below) to facilitate the opening of the anvil **2024**. The elongated channel **2022** and the anvil **2024** may be made of an electrically conductive material (such as metal) so that they may serve as part of an antenna that communicates with sensor(s) in the end effector, as described above. The surgical staple cartridge **2034** could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge **2034**, as was also described above.

As can be seen in FIGS. **34-41**, the surgical end effector **2012** is attached to the tool mounting portion **1300** by an elongated shaft assembly **2008** according to various embodiments. As shown in the illustrated embodiment, the shaft assembly **2008** includes an articulation joint generally indicated as **2011** that enables the surgical end effector **2012** to be selectively articulated about an articulation axis AA-AA that is substantially transverse to a longitudinal tool axis LT-LT. See FIG. **35**. In other embodiments, the articulation joint is omitted. In various embodiments, the shaft assembly **2008** may include a closure tube assembly **2009** that comprises a proximal closure tube **2040** and a distal closure tube **2042** that are pivotably linked by a pivot links **2044** and operably supported on a spine assembly generally depicted as **2049**. In the illustrated embodiment, the spine assembly **2049** comprises a distal spine portion **2050** that is attached to the elongated channel **2022** and is pivotally coupled to the proximal spine portion **2052**. The closure tube assembly **2009** is configured to axially slide on the spine assembly **2049** in response to actuation motions applied thereto. The distal closure tube **2042** includes an opening **2045** into which the tab **2027** on the anvil **2024** is inserted in order to facilitate opening of the anvil **2024** as the distal closure tube **2042** is moved axially in the proximal direction "PD". The closure tubes **2040**, **2042** may be made of electrically conductive material (such as metal) so that they may serve as part of the antenna, as described above. Components of the main drive shaft assembly (e.g., the drive shafts **2048**, **2050**) may be made of a nonconductive material (such as plastic).

In use, it may be desirable to rotate the surgical end effector **2012** about the longitudinal tool axis LT-LT. In at least one embodiment, the tool mounting portion **1300** includes a rotational transmission assembly **2069** that is configured to receive a corresponding rotary output motion from the tool drive assembly **1010** of the robotic system **1000** and convert that rotary output motion to a rotary control motion for rotating the elongated shaft assembly **2008** (and surgical end effector **2012**) about the longitudinal tool axis LT-LT. In various embodiments, for example, the proximal end **2060** of the proximal closure tube **2040** is rotatably supported on the tool mounting plate **1302** of the tool mounting portion **1300** by a forward support cradle **1309** and a closure sled **2100** that is also movably supported on the tool mounting plate **1302**. In at least one form, the rotational transmission assembly **2069** includes a tube gear segment **2062** that is formed on (or attached to) the proximal end **2060** of the proximal closure tube **2040** for operable engagement by a rotational gear assembly **2070** that is operably supported on the tool mounting plate **1302**. As can be seen in FIG. **37**, the rotational gear assembly **2070**, in at least one embodiment, comprises a rotation drive gear **2072** that is coupled to a corresponding first one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **1302** when the tool mounting portion **1300** is coupled to the tool drive assembly **1010**. See FIG. **34**. The rotational gear assembly **2070** further comprises a rotary driven gear **2074** that is rotatably supported on the tool mounting plate **1302** in meshing engagement with the tube gear segment **2062** and the rotation drive gear **2072**. Application of a first rotary output motion from the tool drive assembly **1010** of the robotic system **1000** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **2072**. Rotation of the rotation drive gear **2072** ultimately results in the rotation of the elongated shaft assembly **2008** (and the surgical end effector **2012**) about the longitudinal tool axis LT-LT (represented by arrow "R" in FIG. **37**). It will be appreciated that the application of a rotary output motion from the tool drive assembly **1010** in one direction will result in the rotation of the elongated shaft assembly **2008** and surgical end effector **2012** about the longitudinal tool axis LT-LT in a first direction and an application of the rotary output motion in an opposite direction will result in the rotation of the elongated shaft assembly **2008** and surgical end effector **2012** in a second direction that is opposite to the first direction.

In at least one embodiment, the closure of the anvil **2024** relative to the staple cartridge **2034** is accomplished by axially moving the closure tube assembly **2009** in the distal direction "DD" on the spine assembly **2049**. As indicated above, in various embodiments, the proximal end **2060** of the proximal closure tube **2040** is supported by the closure sled **2100** which comprises a portion of a closure transmission, generally depicted as **2099**. In at least one form, the closure sled **2100** is configured to support the closure tube **2009** on the tool mounting plate **1320** such that the proximal closure tube **2040** can rotate relative to the closure sled **2100**, yet travel axially with the closure sled **2100**. In particular, as can be seen in FIG. **41**, the closure sled **2100** has an upstanding tab **2101** that extends into a radial groove **2063** in the proximal end portion of the proximal closure tube **2040**. In addition, as can be seen in FIGS. **39** and **42**, the closure sled **2100** has a tab portion **2102** that extends through a slot **1305** in the tool mounting plate **1302**. The tab portion **2102** is configured to retain the closure sled **2100** in sliding engagement with the tool mounting plate **1302**. In various embodiments, the closure sled **2100** has an upstanding portion **2104** that has a closure rack gear **2106** formed thereon. The closure rack gear **2106** is configured for driving engagement with a closure gear assembly **2110**. See FIG. **39**.

In various forms, the closure gear assembly **2110** includes a closure spur gear **2112** that is coupled to a corresponding second one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **1302**. See FIG. **34**. Thus, application of a second rotary output motion from the tool drive assembly **1010** of the robotic system **1000** to the corresponding second driven element **1304** will cause rotation of the closure spur gear **2112** when the tool mounting portion **1300** is coupled to the tool drive assembly **1010**. The closure gear assembly **2110** further includes a closure reduction gear set **2114** that is supported in meshing engagement with the closure spur gear **2112**. As can be seen in FIGS. **38** and **39**, the closure reduction gear set **2114** includes a driven gear **2116** that is rotatably supported in meshing engagement with the closure spur gear **2112**. The closure reduction gear set **2114** further includes a first closure drive gear **2118** that is in meshing engagement with a second closure drive gear **2120** that is rotatably supported on the tool mounting plate **1302** in meshing engagement with the closure rack gear **2106**. Thus, application of a second rotary output motion from the tool drive assembly **1010** of the robotic system **1000** to the corresponding second driven element **1304** will cause rotation of the closure spur gear **2112** and the closure transmission **2110** and ultimately drive the closure sled **2100** and closure tube assembly **2009** axially. The axial direction in which the closure tube assembly **2009** moves ultimately depends upon the direction in which the second driven element **1304** is rotated. For example, in response to one rotary output motion received from the tool drive assembly **1010** of the robotic system **1000**, the closure sled **2100** will be driven in the distal direction "DD" and ultimately drive the closure tube assembly **1009** in the distal direction. As the distal closure tube **2042** is driven distally, the end of the closure tube segment **2042** will engage a portion of the anvil **2024** and cause the anvil **2024** to pivot to a closed position. Upon application of an "opening" out put motion from the tool drive assembly **1010** of the robotic system **1000**, the closure sled **2100** and shaft assembly **2008** will be driven in the proximal direction "PD". As the distal closure tube **2042** is driven in the proximal direction, the opening **2045** therein interacts with the tab **2027** on the anvil **2024** to facilitate the opening thereof. In various embodiments, a spring (not shown) may be employed to bias the anvil to the open position when the distal closure tube **2042** has been moved to its starting position. In various embodiments, the various gears of the closure gear assembly **2110** are sized to generate the necessary closure forces needed to satisfactorily close the anvil **2024** onto the tissue to be cut and stapled by the surgical end effector **2012**. For example, the gears of the closure transmission **2110** may be sized to generate approximately 70-120 pounds.

In various embodiments, the cutting instrument **2032** is driven through the surgical end effector **2012** by a knife bar **2200**. See FIGS. **40** and **42**. In at least one form, the knife bar **2200** may be fabricated from, for example, stainless steel or other similar material and has a substantially rectangular cross-sectional shape. Such knife bar configuration is sufficiently rigid to push the cutting instrument **2032** through tissue clamped in the surgical end effector **2012**, while still being flexible enough to enable the surgical end effector **2012** to articulate relative to the proximal closure tube **2040** and the proximal spine portion **2052** about the articulation axis AA-AA as will be discussed in further detail below. As can be seen in FIGS. **43** and **44**, the proximal spine portion **2052** has a rectangular-shaped passage **2054** extending therethrough to provide support to the knife bar **2200** as it is axially pushed therethrough. The proximal spine portion **2052** has a proximal end **2056** that is rotatably mounted to a spine mounting bracket **2057** attached to the tool mounting plate **1032**. See FIG. **42**. Such arrangement permits the proximal spine portion **2052** to rotate, but not move axially, within the proximal closure tube **2040**.

As shown in FIG. **40**, the distal end **2202** of the knife bar **2200** is attached to the cutting instrument **2032**. The proximal end **2204** of the knife bar **2200** is rotatably affixed to a knife rack gear **2206** such that the knife bar **2200** is free to rotate relative to the knife rack gear **2206**. See FIG. **39**. As can be seen in FIGS. **36-41**, the knife rack gear **2206** is slidably supported within a rack housing **2210** that is attached to the tool mounting plate **1302** such that the knife rack gear **2206** is retained in meshing engagement with a knife gear assembly **2220**. More specifically and with reference to FIG. **39**, in at least one embodiment, the knife gear assembly **2220** includes a knife spur gear **2222** that is coupled to a corresponding third one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **1302**. See FIG. **34**. Thus, application of another rotary output motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding third driven element **1304** will cause rotation of the knife spur gear **2222**. The knife gear assembly **2220** further includes a knife gear reduction set **2224** that includes a first knife driven gear **2226** and a second knife drive gear **2228**. The knife gear reduction set **2224** is rotatably mounted to the tool mounting plate **1302** such that the firs knife driven gear **2226** is in meshing engagement with the knife spur gear **2222**. Likewise, the second knife drive gear **2228** is in meshing engagement with a third knife drive gear **2230** that is rotatably supported on the tool mounting plate **1302** in meshing engagement with the knife rack gear **2206**. In various embodiments, the gears of the knife gear assembly **2220** are sized to generate the forces needed to drive the cutting element **2032** through the tissue clamped in the surgical end effector **2012** and actuate the staples therein. For example, the gears of the knife drive assembly **2230** may be sized to generate approximately 40 to 100 pounds. It will be appreciated that the application of a rotary output motion from the tool drive assembly **1010** in one direction will result in the axial movement of the cutting instrument **2032** in a distal direction and application of the rotary output motion in an opposite direction will result in the axial travel of the cutting instrument **2032** in a proximal direction.

In various embodiments, the surgical tool **1200** employs and articulation system **2007** that includes an articulation joint **2011** that enables the surgical end effector **2012** to be articulated about an articulation axis AA-AA that is substantially transverse to the longitudinal tool axis LT-LT. In at least one embodiment, the surgical tool **1200** includes first and second articulation bars **2250***a*, **2250***b* that are slidably supported within corresponding passages **2053** provided through the proximal spine portion **2052**. See FIGS. **42** and **44**. In at least one form, the first and second articulation bars **2250***a*, **2250***b* are actuated by an articulation transmission generally designated as **2249** that is operably supported on the tool mounting plate **1032**. Each of the articulation bars **2250***a*, **2250***b* has a proximal end **2252** that has a guide rod protruding therefrom which extend laterally through a corresponding slot in the proximal end portion of the proximal spine portion **2052** and into a corresponding arcuate slot in an articulation nut **2260** which comprises a portion of the articulation transmission. FIG. **43** illustrates articulation bar **2250***a*. It will be understood that articulation bar **2250***b* is similarly constructed. As can be seen in FIG. **40**, for example, the articulation bar **2250***a* has a guide rod **2254** which extends laterally through a corresponding slot **2058** in the proximal end portion **2056** of the distal spine portion **2050** and into a corresponding arcuate slot **2262** in the articulation nut **2260**. In addition, the articulation bar **2250***a* has a distal end **2251***a* that is pivotally coupled to the distal spine portion **2050** by, for example, a pin **2253***a* and articulation bar **2250***b* has a distal end **2251***b* that is pivotally coupled to the distal spine portion **2050** by, for example, a pin **2253***b*. In particular, the articulation bar **2250***a* is laterally offset in a first lateral direction from the longitudinal tool axis LT-LT and the articulation bar **2250***b* is laterally offset in a second lateral direction from the longitudinal tool axis LT-LT. Thus, axial movement of the articulation bars **2250***a* and **2250***b* in opposing directions will result in the articulation of the distal spine portion **2050** as well as the surgical end effector **2012** attached thereto about the articulation axis AA-AA as will be discussed in further detail below.

Articulation of the surgical end effector **2012** is controlled by rotating the articulation nut **2260** about the longitudinal tool axis LT-LT. The articulation nut **2260** is rotatably journaled on the proximal end portion **2056** of the distal spine portion **2050** and is rotatably driven thereon by an articulation gear assembly **2270**. More specifically and with reference to FIG. **37**, in at least one embodiment, the articulation gear assembly **2270** includes an articulation spur gear **2272** that is coupled to a corresponding fourth one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **1302**. See FIG. **34**. Thus, application of another rotary input motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding fourth driven element **1304** will cause rotation of the articulation spur gear **2272** when the interface **1230** is coupled to the tool holder **1270**. An articulation drive gear **2274** is rotatably supported on the tool mounting plate **1302** in meshing engagement with the articulation spur gear **2272** and a gear portion **2264** of the articulation nut **2260** as shown. As can be seen in FIGS. **42** and **43**, the articulation nut **2260** has a shoulder **2266** formed thereon that defines an annular groove **2267** for receiving retaining posts **2268** therein. Retaining posts **2268** are attached to the tool mounting plate **1302** and serve to prevent the articulation nut **2260** from moving axially on the proximal spine portion **2052** while maintaining the ability to be rotated relative thereto. Thus, rotation of the articulation nut **2260** in a first direction, will result in the axial movement of the articulation bar **2250***a* in a distal direction "DD" and the axial movement of the articulation bar **2250***b* in a proximal direction "PD" because of the interaction of the guide rods **2254** with the spiral slots **2262** in the articulation gear **2260**. Similarly, rotation of the articulation nut **2260** in a second direction that is opposite to the first direction will result in the axial movement of the articulation bar **2250***a* in the proximal direction "PD" as well as cause articulation bar **2250***b* to axially move in the distal direction "DD". Thus, the surgical end effector **2012** may be selectively articulated about articulation axis "AA-AA" in a first direction "FD" by simultaneously moving the articulation bar **2250***a* in the distal direction "DD" and the articulation bar **2250***b* in the proximal direction "PD". Likewise, the surgical end effector **2012** may be selectively articulated about the articulation axis "AA-AA" in a second direction "SD" by simultaneously moving the articulation bar **2250***a* in the proximal direction "PD" and the articulation bar **2250***b* in the distal direction "DD." See FIG. **35**.

The tool embodiment described above employs an interface arrangement that is particularly well-suited for mounting the robotically controllable medical tool onto at least one form of robotic arm arrangement that generates at least four different rotary control motions. Those of ordinary skill in the art will appreciate that such rotary output motions may be selectively controlled through the programmable control systems employed by the robotic system/controller. For example, the tool arrangement described above may be well-suited for use with those robotic systems manufactured by Intuitive Surgical, Inc. of Sunnyvale, Calif., U.S.A., many of which may be described in detail in various patents incorporated herein by reference. The unique and novel aspects of various embodiments of the present invention serve to utilize the rotary output motions supplied by the robotic system to generate specific control motions having sufficient magnitudes that enable end effectors to cut and staple tissue. Thus, the unique arrangements and principles of various embodiments of the present invention may enable a variety of different forms of the tool systems disclosed and claimed herein to be effectively employed in connection with other types and forms of robotic systems that supply programmed rotary or other output motions. In addition, as will become further apparent as the present Detailed Description proceeds, various end effector embodiments of the present invention that require other forms of actuation motions may also be effectively actuated utilizing one or more of the control motions generated by the robotic system.

FIGS. **46-50** illustrate yet another surgical tool **2300** that may be effectively employed in connection with the robotic system **1000** that has a tool drive assembly that is operably coupled to a controller of the robotic system that is operable by inputs from an operator and which is configured to provide at least one rotary output motion to at least one rotatable body portion supported on the tool drive assembly. In various forms, the surgical tool **2300** includes a surgical end effector **2312** that includes an elongated channel **2322** and a pivotally translatable clamping member, such as an anvil **2324**, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector **2312**. As shown in the illustrated embodiment, the surgical end effector **2312** may include, in addition to the previously-mentioned elongated channel **2322** and anvil **2324**, a cutting instrument **2332** that has a sled portion **2333** formed thereon, a surgical staple cartridge **2334** that is seated in the elongated channel **2322**, and a rotary end effector drive shaft **2336** that has a helical screw thread formed thereon. The cutting instrument **2332** may be, for example, a knife. As will be discussed in further detail below, rotation of the end effector drive shaft **2336** will cause the cutting instrument **2332** and sled portion **2333** to axially travel through the surgical staple cartridge **2334** to move between a starting position and an ending position. The direction of axial travel of the cutting instrument **2332** depends upon the direction in which the end effector drive shaft **2336** is rotated. The anvil **2324** may be pivotably opened and closed at a pivot point **2325** connected to the proximate end of the elongated channel **2322**. The anvil **2324** may also include a tab **2327** at its proximate end that operably interfaces with a component of the mechanical closure system (described further below) to open and close the anvil

2324. When the end effector drive shaft 2336 is rotated, the cutting instrument 2332 and sled 2333 will travel longitudinally through the surgical staple cartridge 2334 from the starting position to the ending position, thereby cutting tissue clamped within the surgical end effector 2312. The movement of the sled 2333 through the surgical staple cartridge 2334 causes the staples therein to be driven through the severed tissue and against the closed anvil 2324, which turns the staples to fasten the severed tissue. In one form, the elongated channel 2322 and the anvil 2324 may be made of an electrically conductive material (such as metal) so that they may serve as part of the antenna that communicates with sensor(s) in the end effector, as described above. The surgical staple cartridge 2334 could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge 2334, as described above.

It should be noted that although the embodiments of the surgical tool 2300 described herein employ a surgical end effector 2312 that staples the severed tissue, in other embodiments different techniques for fastening or sealing the severed tissue may be used. For example, end effectors that use RF energy or adhesives to fasten the severed tissue may also be used. U.S. Pat. No. 5,709,680, entitled "Electrosurgical Hemostatic Device" to Yates et al., and U.S. Pat. No. 5,688,270, entitled "Electrosurgical Hemostatic Device With Recessed And/Or Offset Electrodes" to Yates et al., which are incorporated herein by reference, discloses cutting instruments that use RF energy to fasten the severed tissue. U.S. patent application Ser. No. 11/267,811 to Morgan et al., now U.S. Pat. No. 7,673,783, and U.S. patent application Ser. No. 11/267,383 to Shelton et al., now U.S. Pat. No. 7,607,557, which are also incorporated herein by reference, disclose cutting instruments that use adhesives to fasten the severed tissue. Accordingly, although the description herein refers to cutting/stapling operations and the like, it should be recognized that this is an exemplary embodiment and is not meant to be limiting. Other tissue-fastening techniques may also be used.

In the illustrated embodiment, the surgical end effector 2312 is coupled to an elongated shaft assembly 2308 that is coupled to a tool mounting portion 2460 and defines a longitudinal tool axis LT-LT. In this embodiment, the elongated shaft assembly 2308 does not include an articulation joint. Those of ordinary skill in the art will understand that other embodiments may have an articulation joint therein. In at least one embodiment, the elongated shaft assembly 2308 comprises a hollow outer tube 2340 that is rotatably supported on a tool mounting plate 2462 of a tool mounting portion 2460 as will be discussed in further detail below. In various embodiments, the elongated shaft assembly 2308 further includes a distal spine shaft 2350. Distal spine shaft 2350 has a distal end portion 2354 that is coupled to, or otherwise integrally formed with, a distal stationary base portion 2360 that is non-movably coupled to the channel 2322. See FIGS. 47-49.

As shown in FIG. 47, the distal spine shaft 2350 has a proximal end portion 2351 that is slidably received within a slot 2355 in a proximal spine shaft 2353 that is non-movably supported within the hollow outer tube 2340 by at least one support collar 2357. As can be further seen in FIGS. 47 and 48, the surgical tool 2300 includes a closure tube 2370 that is constrained to only move axially relative to the distal stationary base portion 2360. The closure tube 2370 has a proximal end 2372 that has an internal thread 2374 formed therein that is in threaded engagement with a transmission arrangement, generally depicted as 2375 that is operably supported on the tool mounting plate 2462. In various forms, the transmission arrangement 2375 includes a rotary drive shaft assembly, generally designated as 2381. When rotated, the rotary drive shaft assembly 2381 will cause the closure tube 2370 to move axially as will be describe in further detail below. In at least one form, the rotary drive shaft assembly 2381 includes a closure drive nut 2382 of a closure clutch assembly generally designated as 2380. More specifically, the closure drive nut 2382 has a proximal end portion 2384 that is rotatably supported relative to the outer tube 2340 and is in threaded engagement with the closure tube 2370. For assembly purposes, the proximal end portion 2384 may be threadably attached to a retention ring 2386. Retention ring 2386, in cooperation with an end 2387 of the closure drive nut 2382, defines an annular slot 2388 into which a shoulder 2392 of a locking collar 2390 extends. The locking collar 2390 is non-movably attached (e.g., welded, glued, etc.) to the end of the outer tube 2340. Such arrangement serves to affix the closure drive nut 2382 to the outer tube 2340 while enabling the closure drive nut 2382 to rotate relative to the outer tube 2340. The closure drive nut 2382 further has a distal end 2383 that has a threaded portion 2385 that threadably engages the internal thread 2374 of the closure tube 2370. Thus, rotation of the closure drive nut 2382 will cause the closure tube 2370 to move axially as represented by arrow "D" in FIG. 48.

Closure of the anvil 2324 and actuation of the cutting instrument 2332 are accomplished by control motions that are transmitted by a hollow drive sleeve 2400. As can be seen in FIGS. 47 and 48, the hollow drive sleeve 2400 is rotatably and slidably received on the distal spine shaft 2350. The drive sleeve 2400 has a proximal end portion 2401 that is rotatably mounted to the proximal spine shaft 2353 that protrudes from the tool mounting portion 2460 such that the drive sleeve 2400 may rotate relative thereto. See FIG. 47. As can also be seen in FIGS. 47-49, the drive sleeve 2400 is rotated about the longitudinal tool axis "LT-LT" by a drive shaft 2440. The drive shaft 2440 has a drive gear 2444 that is attached to its distal end 2442 and is in meshing engagement with a driven gear 2450 that is attached to the drive sleeve 2400.

The drive sleeve 2400 further has a distal end portion 2402 that is coupled to a closure clutch 2410 portion of the closure clutch assembly 2380 that has a proximal face 2412 and a distal face 2414. The proximal face 2412 has a series of proximal teeth 2416 formed thereon that are adapted for selective engagement with corresponding proximal teeth cavities 2418 formed in the proximal end portion 2384 of the closure drive nut 2382. Thus, when the proximal teeth 2416 are in meshing engagement with the proximal teeth cavities 2418 in the closure drive nut 2382, rotation of the drive sleeve 2400 will result in rotation of the closure drive nut 2382 and ultimately cause the closure tube 2370 to move axially as will be discussed in further detail below.

As can be most particularly seen in FIGS. 47 and 48, the distal face 2414 of the drive clutch portion 2410 has a series of distal teeth 2415 formed thereon that are adapted for selective engagement with corresponding distal teeth cavities 2426 formed in a face plate portion 2424 of a knife drive shaft assembly 2420. In various embodiments, the knife drive shaft assembly 2420 comprises a hollow knife shaft segment 2430 that is rotatably received on a corresponding portion of the distal spine shaft 2350 that is attached to or protrudes from the stationary base 2360. When the distal teeth 2415 of the closure clutch portion 2410 are in meshing engagement with the distal teeth cavities 2426 in the face plate portion 2424, rotation of the drive sleeve 2400 will result in rotation of the drive shaft segment 2430 about the stationary shaft 2350. As can be seen in FIGS. 47-49, a knife drive gear 2432 is attached to the drive shaft segment **2430** and is meshing engagement with a drive knife gear **2434** that is attached to the end effector drive shaft **2336**. Thus, rotation of the drive shaft segment **2430** will result in the rotation of the end effector drive shaft **2336** to drive the cutting instrument **2332** and sled **2333** distally through the surgical staple cartridge **2334** to cut and staple tissue clamped within the surgical end effector **2312**. The sled **2333** may be made of, for example, plastic, and may have a sloped distal surface. As the sled **2333** traverses the elongated channel **2322**, the sloped forward surface of the sled **2333** pushes up or "drive" the staples in the surgical staple cartridge **2334** through the clamped tissue and against the anvil **2324**. The anvil **2324** turns or "forms" the staples, thereby stapling the severed tissue. As used herein, the term "fire" refers to the initiation of actions required to drive the cutting instrument and sled portion in a distal direction through the surgical staple cartridge to cut the tissue clamped in the surgical end effector and drive the staples through the severed tissue.

In use, it may be desirable to rotate the surgical end effector **2312** about the longitudinal tool axis LT-LT. In at least one embodiment, the transmission arrangement **2375** includes a rotational transmission assembly **2465** that is configured to receive a corresponding rotary output motion from the tool drive assembly **1010** of the robotic system **1000** and convert that rotary output motion to a rotary control motion for rotating the elongated shaft assembly **2308** (and surgical end effector **2312**) about the longitudinal tool axis LT-LT. As can be seen in FIG. **50**, a proximal end **2341** of the outer tube **2340** is rotatably supported within a cradle arrangement **2343** attached to the tool mounting plate **2462** of the tool mounting portion **2460**. A rotation gear **2345** is formed on or attached to the proximal end **2341** of the outer tube **2340** of the elongated shaft assembly **2308** for meshing engagement with a rotation gear assembly **2470** operably supported on the tool mounting plate **2462**. In at least one embodiment, a rotation drive gear **2472** is coupled to a corresponding first one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **2462** when the tool mounting portion **2460** is coupled to the tool drive assembly **1010**. See FIGS. **34** and **50**. The rotation drive assembly **2470** further comprises a rotary driven gear **2474** that is rotatably supported on the tool mounting plate **2462** in meshing engagement with the rotation gear **2345** and the rotation drive gear **2472**. Application of a first rotary output motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **2472** by virtue of being operably coupled thereto. Rotation of the rotation drive gear **2472** ultimately results in the rotation of the elongated shaft assembly **2308** (and the end effector **2312**) about the longitudinal tool axis LT-LT (primary rotary motion).

Closure of the anvil **2324** relative to the staple cartridge **2034** is accomplished by axially moving the closure tube **2370** in the distal direction "DD". Axial movement of the closure tube **2370** in the distal direction "DD" is accomplished by applying a rotary control motion to the closure drive nut **2382**. To apply the rotary control motion to the closure drive nut **2382**, the closure clutch **2410** must first be brought into meshing engagement with the proximal end portion **2384** of the closure drive nut **2382**. In various embodiments, the transmission arrangement **2375** further includes a shifter drive assembly **2480** that is operably supported on the tool mounting plate **2462**. More specifically and with reference to FIG. **50**, it can be seen that a proximal end portion **2359** of the proximal spine portion **2353** extends through the rotation gear **2345** and is rotatably coupled to a shifter gear rack **2481** that is slidably affixed to the tool mounting plate **2462** through slots **2482**. The shifter drive assembly **2480** further comprises a shifter drive gear **2483** that is coupled to a corresponding second one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **2462** when the tool mounting portion **2460** is coupled to the tool holder **1270**. See FIGS. **34** and **50**. The shifter drive assembly **2480** further comprises a shifter driven gear **2478** that is rotatably supported on the tool mounting plate **2462** in meshing engagement with the shifter drive gear **2483** and the shifter rack gear **2482**. Application of a second rotary output motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding driven element **1304** will thereby cause rotation of the shifter drive gear **2483** by virtue of being operably coupled thereto. Rotation of the shifter drive gear **2483** ultimately results in the axial movement of the shifter gear rack **2482** and the proximal spine portion **2353** as well as the drive sleeve **2400** and the closure clutch **2410** attached thereto. The direction of axial travel of the closure clutch **2410** depends upon the direction in which the shifter drive gear **2483** is rotated by the robotic system **1000**. Thus, rotation of the shifter drive gear **2483** in a first rotary direction will result in the axial movement of the closure clutch **2410** in the proximal direction "PD" to bring the proximal teeth **2416** into meshing engagement with the proximal teeth cavities **2418** in the closure drive nut **2382**. Conversely, rotation of the shifter drive gear **2483** in a second rotary direction (opposite to the first rotary direction) will result in the axial movement of the closure clutch **2410** in the distal direction "DD" to bring the distal teeth **2415** into meshing engagement with corresponding distal teeth cavities **2426** formed in the face plate portion **2424** of the knife drive shaft assembly **2420**.

Once the closure clutch **2410** has been brought into meshing engagement with the closure drive nut **2382**, the closure drive nut **2382** is rotated by rotating the closure clutch **2410**. Rotation of the closure clutch **2410** is controlled by applying rotary output motions to a rotary drive transmission portion **2490** of transmission arrangement **2375** that is operably supported on the tool mounting plate **2462** as shown in FIG. **50**. In at least one embodiment, the rotary drive transmission **2490** includes a rotary drive assembly **2490'** that includes a gear **2491** that is coupled to a corresponding third one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **2462** when the tool mounting portion **2460** is coupled to the tool holder **1270**. See FIGS. **34** and **50**. The rotary drive transmission **2490** further comprises a first rotary driven gear **2492** that is rotatably supported on the tool mounting plate **2462** in meshing engagement with a second rotary driven gear **2493** and the rotary drive gear **2491**. The second rotary driven gear **2493** is coupled to a proximal end portion **2443** of the drive shaft **2440**.

Rotation of the rotary drive gear **2491** in a first rotary direction will result in the rotation of the drive shaft **2440** in a first direction. Conversely, rotation of the rotary drive gear **2491** in a second rotary direction (opposite to the first rotary direction) will cause the drive shaft **2440** to rotate in a second direction. As indicated above, the drive shaft **2440** has a drive gear **2444** that is attached to its distal end **2442** and is in meshing engagement with a driven gear **2450** that is attached to the drive sleeve **2400**. Thus, rotation of the drive shaft **2440** results in rotation of the drive sleeve **2400**.

A method of operating the surgical tool **2300** will now be described. Once the tool mounting portion **2462** has been operably coupled to the tool holder **1270** of the robotic system **1000** and oriented into position adjacent the target tissue to be cut and stapled, if the anvil **2334** is not already in the open position (FIG. **47**), the robotic system **1000** may apply the first rotary output motion to the shifter drive gear **2483** which results in the axial movement of the closure clutch **2410** into meshing engagement with the closure drive nut **2382** (if it is not already in meshing engagement therewith). See FIG. **48**. Once the controller **1001** of the robotic system **1000** has confirmed that the closure clutch **2410** is meshing engagement with the closure drive nut **2382** (e.g., by means of sensor(s)) in the surgical end effector **2312** that are in communication with the robotic control system), the robotic controller **1001** may then apply a second rotary output motion to the rotary drive gear **2492** which, as was described above, ultimately results in the rotation of the rotary drive nut **2382** in the first direction which results in the axial travel of the closure tube **2370** in the distal direction "DD". As the closure tube **2370** moved in the distal direction, it contacts a portion of the anvil **2323** and causes the anvil **2324** to pivot to the closed position to clamp the target tissue between the anvil **2324** and the surgical staple cartridge **2334**. Once the robotic controller **1001** determines that the anvil **2334** has been pivoted to the closed position by corresponding sensor(s) in the surgical end effector **2312** in communication therewith, the robotic system **1000** discontinues the application of the second rotary output motion to the rotary drive gear **2491**. The robotic controller **1001** may also provide the surgeon with an indication that the anvil **2334** has been fully closed. The surgeon may then initiate the firing procedure. In alternative embodiments, the firing procedure may be automatically initiated by the robotic controller **1001**. The robotic controller **1001** then applies the primary rotary control motion **2483** to the shifter drive gear **2483** which results in the axial movement of the closure clutch **2410** into meshing engagement with the face plate portion **2424** of the knife drive shaft assembly **2420**. See FIG. **49**. Once the controller **1001** of the robotic system **1000** has confirmed that the closure clutch **2410** is meshing engagement with the face plate portion **2424** (by means of sensor(s)) in the end effector **2312** that are in communication with the robotic controller **1001**), the robotic controller **1001** may then apply the second rotary output motion to the rotary drive gear **2492** which, as was described above, ultimately results in the axial movement of the cutting instrument **2332** and sled portion **2333** in the distal direction "DD" through the surgical staple cartridge **2334**. As the cutting instrument **2332** moves distally through the surgical staple cartridge **2334**, the tissue clamped therein is severed. As the sled portion **2333** is driven distally, it causes the staples within the surgical staple cartridge to be driven through the severed tissue into forming contact with the anvil **2324**. Once the robotic controller **1001** has determined that the cutting instrument **2324** has reached the end position within the surgical staple cartridge **2334** (by means of sensor(s)) in the end effector **2312** that are in communication with the robotic controller **1001**), the robotic controller **1001** discontinues the application of the second rotary output motion to the rotary drive gear **2491**. Thereafter, the robotic controller **1001** applies the secondary rotary output motion to the rotary drive gear **2491** which ultimately results in the axial travel of the cutting instrument **2332** and sled portion **2333** in the proximal direction "PD" to the starting position. Once the robotic controller **1001** has determined that the cutting instrument **2324** has reached the staring position by means of sensor(s) in the surgical end effector **2312** that are in communication with the robotic controller **1001**, the robotic controller **1001** discontinues the application of the secondary rotary output motion to the rotary drive gear **2491**. Thereafter, the robotic controller **1001** applies the primary rotary output motion to the shifter drive gear **2483** to cause the closure clutch **2410** to move into engagement with the rotary drive nut **2382**. Once the closure clutch **2410** has been moved into meshing engagement with the rotary drive nut **2382**, the robotic controller **1001** then applies the secondary output motion to the rotary drive gear **2491** which ultimately results in the rotation of the rotary drive nut **2382** in the second direction to cause the closure tube **2370** to move in the proximal direction "PD". As can be seen in FIGS. **47-49**, the closure tube **2370** has an opening **2345** therein that engages the tab **2327** on the anvil **2324** to cause the anvil **2324** to pivot to the open position. In alternative embodiments, a spring may also be employed to pivot the anvil **2324** to the open position when the closure tube **2370** has been returned to the starting position (FIG. **47**).

FIGS. **51-55** illustrate yet another surgical tool **2500** that may be effectively employed in connection with the robotic system **1000**. In various forms, the surgical tool **2500** includes a surgical end effector **2512** that includes a "first portion" in the form of an elongated channel **2522** and a "second movable portion" in the form of a pivotally translatable clamping member, such as an anvil **2524**, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector **2512**. As shown in the illustrated embodiment, the surgical end effector **2512** may include, in addition to the previously-mentioned elongated channel **2522** and anvil **2524**, a "third movable portion" in the form of a cutting instrument **2532**, a sled (not shown), and a surgical staple cartridge **2534** that is removably seated in the elongated channel **2522**. The cutting instrument **2532** may be, for example, a knife. The anvil **2524** may be pivotably opened and closed at a pivot point **2525** connected to the proximate end of the elongated channel **2522**. The anvil **2524** may also include a tab **2527** at its proximate end that is configured to operably interface with a component of the mechanical closure system (described further below) to open and close the anvil **2524**. When actuated, the knife **2532** and sled travel longitudinally along the elongated channel **2522**, thereby cutting tissue clamped within the surgical end effector **2512**. The movement of the sled along the elongated channel **2522** causes the staples of the surgical staple cartridge **2534** to be driven through the severed tissue and against the closed anvil **2524**, which turns the staples to fasten the severed tissue. In one form, the elongated channel **2522** and the anvil **2524** may be made of an electrically conductive material (such as metal) so that they may serve as part of the antenna that communicates with sensor(s) in the surgical end effector, as described above. The surgical staple cartridge **2534** could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge **2534**, as described above.

It should be noted that although the embodiments of the surgical tool **2500** described herein employ a surgical end effector **2512** that staples the severed tissue, in other embodiments different techniques for fastening or sealing the severed tissue may be used. For example, end effectors that use RF energy or adhesives to fasten the severed tissue may also be used. U.S. Pat. No. 5,709,680, entitled "Electrosurgical Hemostatic Device" to Yates et al., and U.S. Pat. No. 5,688,270, entitled "Electrosurgical Hemostatic Device With Recessed And/Or Offset Electrodes" to Yates et al., which are incorporated herein by reference, discloses cutting instruments that use RF energy to fasten the severed tissue. U.S. patent application Ser. No. 11/267,811 to Morgan et al., now U.S. Pat. No. 7,673,783, and U.S. patent application Ser. No. 11/267,383 to Shelton et al., now U.S. Pat. No. 7,607,557, which are also incorporated herein by reference, disclose cutting instruments that use adhesives to fasten the severed tissue. Accordingly, although the description herein refers to cutting/stapling operations and the like, it should be recognized that this is an exemplary embodiment and is not meant to be limiting. Other tissue-fastening techniques may also be used.

In the illustrated embodiment, the elongated channel **2522** of the surgical end effector **2512** is coupled to an elongated shaft assembly **2508** that is coupled to a tool mounting portion **2600**. In at least one embodiment, the elongated shaft assembly **2508** comprises a hollow spine tube **2540** that is non-movably coupled to a tool mounting plate **2602** of the tool mounting portion **2600**. As can be seen in FIGS. **52** and **53**, the proximal end **2523** of the elongated channel **2522** comprises a hollow tubular structure configured to be attached to the distal end **2541** of the spine tube **2540**. In one embodiment, for example, the proximal end **2523** of the elongated channel **2522** is welded or glued to the distal end of the spine tube **2540**.

As can be further seen in FIGS. **52** and **53**, in at least one non-limiting embodiment, the surgical tool **2500** further includes an axially movable actuation member in the form of a closure tube **2550** that is constrained to move axially relative to the elongated channel **2522** and the spine tube **1540**. The closure tube **2550** has a proximal end **2552** that has an internal thread **2554** formed therein that is in threaded engagement with a rotatably movable portion in the form of a closure drive nut **2560**. More specifically, the closure drive nut **2560** has a proximal end portion **2562** that is rotatably supported relative to the elongated channel **2522** and the spine tube **2540**. For assembly purposes, the proximal end portion **2562** is threadably attached to a retention ring **2570**. The retention ring **2570** is received in a groove **2529** formed between a shoulder **2527** on the proximal end **2523** of the elongated channel **2522** and the distal end **2541** of the spine tube **1540**. Such arrangement serves to rotatably support the closure drive nut **2560** within the elongated channel **2522**. Rotation of the closure drive nut **2560** will cause the closure tube **2550** to move axially as represented by arrow "D" in FIG. **52**.

Extending through the spine tube **2540** and the closure drive nut **2560** is a drive member which, in at least one embodiment, comprises a knife bar **2580** that has a distal end portion **2582** that is rotatably coupled to the cutting instrument **2532** such that the knife bar **2580** may rotate relative to the cutting instrument **2582**. As can be seen in FIG. **52-54**, the closure drive nut **2560** has a slot **2564** therein through which the knife bar **2580** can slidably extend. Such arrangement permits the knife bar **2580** to move axially relative to the closure drive nut **2560**. However, rotation of the knife bar **2580** about the longitudinal tool axis LT-LT will also result in the rotation of the closure drive nut **2560**. The axial direction in which the closure tube **2550** moves ultimately depends upon the direction in which the knife bar **2580** and the closure drive nut **2560** are rotated. As the closure tube **2550** is driven distally, the distal end thereof will contact the anvil **2524** and cause the anvil **2524** to pivot to a closed position. Upon application of an opening rotary output motion from the robotic system **1000**, the closure tube **2550** will be driven in the proximal direction "PD" and pivot the anvil **2524** to the open position by virtue of the engagement of the tab **2527** with the opening **2555** in the closure tube **2550**.

In use, it may be desirable to rotate the surgical end effector **2512** about the longitudinal tool axis LT-LT. In at least one embodiment, the tool mounting portion **2600** is configured to receive a corresponding first rotary output motion from the robotic system **1000** and convert that first rotary output motion to a rotary control motion for rotating the elongated shaft assembly **2508** about the longitudinal tool axis LT-LT. As can be seen in FIG. **55**, a proximal end **2542** of the hollow spine tube **2540** is rotatably supported within a cradle arrangement **2603** attached to a tool mounting plate **2602** of the tool mounting portion **2600**. Various embodiments of the surgical tool **2500** further include a transmission arrangement, generally depicted as **2605**, that is operably supported on the tool mounting plate **2602**. In various forms the transmission arrangement **2605** include a rotation gear **2544** that is formed on or attached to the proximal end **2542** of the spine tube **2540** for meshing engagement with a rotation drive assembly **2610** that is operably supported on the tool mounting plate **2602**. In at least one embodiment, a rotation drive gear **2612** is coupled to a corresponding first one of the rotational bodies, driven discs or elements **1304** on the adapter side of the tool mounting plate **2602** when the tool mounting portion **2600** is coupled to the tool holder **1270**. See FIGS. **34** and **55**. The rotation drive assembly **2610** further comprises a rotary driven gear **2614** that is rotatably supported on the tool mounting plate **2602** in meshing engagement with the rotation gear **2544** and the rotation drive gear **2612**. Application of a first rotary output motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding driven rotational body **1304** will thereby cause rotation of the rotation drive gear **2612** by virtue of being operably coupled thereto. Rotation of the rotation drive gear **2612** ultimately results in the rotation of the elongated shaft assembly **2508** (and the end effector **2512**) about the longitudinal tool axis LT-LT.

Closure of the anvil **2524** relative to the surgical staple cartridge **2534** is accomplished by axially moving the closure tube **2550** in the distal direction "DD". Axial movement of the closure tube **2550** in the distal direction "DD" is accomplished by applying a rotary control motion to the closure drive nut **2382**. In various embodiments, the closure drive nut **2560** is rotated by applying a rotary output motion to the knife bar **2580**. Rotation of the knife bar **2580** is controlled by applying rotary output motions to a rotary closure system **2620** that is operably supported on the tool mounting plate **2602** as shown in FIG. **55**. In at least one embodiment, the rotary closure system **2620** includes a closure drive gear **2622** that is coupled to a corresponding second one of the driven rotatable body portions discs or elements **1304** on the adapter side of the tool mounting plate **2462** when the tool mounting portion **2600** is coupled to the tool holder **1270**. See FIGS. **34** and **55**. The closure drive gear **2622**, in at least one embodiment, is in meshing driving engagement with a closure gear train, generally depicted as **2623**. The closure gear drive rain **2623** comprises a first driven closure gear **2624** that is rotatably supported on the tool mounting plate **2602**. The first closure driven gear **2624** is attached to a second closure driven gear **2626** by a drive shaft **2628**. The second closure driven gear **2626** is in meshing engagement with a third closure driven gear **2630** that is rotatably supported on the tool mounting plate **2602**. Rotation of the closure drive gear **2622** in a second rotary direction will result in the rotation of the third closure driven gear **2630** in a second direction. Conversely, rotation of the closure drive gear **2483** in a secondary rotary direction (opposite to the second rotary direction) will cause the third closure driven gear **2630** to rotate in a secondary direction.

As can be seen in FIG. **55**, a drive shaft assembly **2640** is coupled to a proximal end of the knife bar **2580**. In various embodiments, the drive shaft assembly **2640** includes a proximal portion **2642** that has a square cross-sectional shape. The proximal portion **2642** is configured to slideably engage a correspondingly shaped aperture in the third driven gear **2630**. Such arrangement results in the rotation of the drive shaft assembly **2640** (and knife bar **2580**) when the third driven gear **2630** is rotated. The drive shaft assembly **2640** is axially advanced in the distal and proximal directions by a knife drive assembly **2650**. One form of the knife drive assembly **2650** comprises a rotary drive gear **2652** that is coupled to a corresponding third one of the driven rotatable body portions, discs or elements **1304** on the adapter side of the tool mounting plate **2462** when the tool mounting portion **2600** is coupled to the tool holder **1270**. See FIGS. **34** and **55**. The rotary driven gear **2652** is in meshing driving engagement with a gear train, generally depicted as **2653**. In at least one form, the gear train **2653** further comprises a first rotary driven gear assembly **2654** that is rotatably supported on the tool mounting plate **2602**. The first rotary driven gear assembly **2654** is in meshing engagement with a third rotary driven gear assembly **2656** that is rotatably supported on the tool mounting plate **2602** and which is in meshing engagement with a fourth rotary driven gear assembly **2658** that is in meshing engagement with a threaded portion **2644** of the drive shaft assembly **2640**. Rotation of the rotary drive gear **2652** in a third rotary direction will result in the axial advancement of the drive shaft assembly **2640** and knife bar **2580** in the distal direction "DD". Conversely, rotation of the rotary drive gear **2652** in a tertiary rotary direction (opposite to the third rotary direction) will cause the drive shaft assembly **2640** and the knife bar **2580** to move in the proximal direction.

A method of operating the surgical tool **2500** will now be described. Once the tool mounting portion **2600** has been operably coupled to the tool holder **1270** of the robotic system **1000**, the robotic system **1000** can orient the surgical end effector **2512** in position adjacent the target tissue to be cut and stapled. If the anvil **2524** is not already in the open position (FIG. **52**), the robotic system **1000** may apply the second rotary output motion to the closure drive gear **2622** which results in the rotation of the knife bar **2580** in a second direction. Rotation of the knife bar **2580** in the second direction results in the rotation of the closure drive nut **2560** in a second direction. As the closure drive nut **2560** rotates in the second direction, the closure tube **2550** moves in the proximal direction "PD". As the closure tube **2550** moves in the proximal direction "PD", the tab **2527** on the anvil **2524** interfaces with the opening **2555** in the closure tube **2550** and causes the anvil **2524** to pivot to the open position. In addition or in alternative embodiments, a spring (not shown) may be employed to pivot the anvil **2354** to the open position when the closure tube **2550** has been returned to the starting position (FIG. **52**). The opened surgical end effector **2512** may then be manipulated by the robotic system **1000** to position the target tissue between the open anvil **2524** and the surgical staple cartridge **2534**. Thereafter, the surgeon may initiate the closure process by activating the robotic control system **1000** to apply the second rotary output motion to the closure drive gear **2622** which, as was described above, ultimately results in the rotation of the closure drive nut **2382** in the second direction which results in the axial travel of the closure tube **2250** in the distal direction "DD". As the closure tube **2550** moves in the distal direction, it contacts a portion of the anvil **2524** and causes the anvil **2524** to pivot to the closed position to clamp the target tissue between the anvil **2524** and the staple cartridge **2534**. Once the robotic controller **1001** determines that the anvil **2524** has been pivoted to the closed position by corresponding sensor(s) in the end effector **2512** that are in communication therewith, the robotic controller **1001** discontinues the application of the second rotary output motion to the closure drive gear **2622**. The robotic controller **1001** may also provide the surgeon with an indication that the anvil **2524** has been fully closed. The surgeon may then initiate the firing procedure. In alternative embodiments, the firing procedure may be automatically initiated by the robotic controller **1001**.

After the robotic controller **1001** has determined that the anvil **2524** is in the closed position, the robotic controller **1001** then applies the third rotary output motion to the rotary drive gear **2652** which results in the axial movement of the drive shaft assembly **2640** and knife bar **2580** in the distal direction "DD". As the cutting instrument **2532** moves distally through the surgical staple cartridge **2534**, the tissue clamped therein is severed. As the sled portion (not shown) is driven distally, it causes the staples within the surgical staple cartridge **2534** to be driven through the severed tissue into forming contact with the anvil **2524**. Once the robotic controller **1001** has determined that the cutting instrument **2532** has reached the end position within the surgical staple cartridge **2534** by means of sensor(s) in the surgical end effector **2512** that are in communication with the robotic controller **1001**, the robotic controller **1001** discontinues the application of the second rotary output motion to the rotary drive gear **2652**. Thereafter, the robotic controller **1001** applies the secondary rotary control motion to the rotary drive gear **2652** which ultimately results in the axial travel of the cutting instrument **2532** and sled portion in the proximal direction "PD" to the starting position. Once the robotic controller **1001** has determined that the cutting instrument **2524** has reached the staring position by means of sensor(s) in the end effector **2512** that are in communication with the robotic controller **1001**, the robotic controller **1001** discontinues the application of the secondary rotary output motion to the rotary drive gear **2652**. Thereafter, the robotic controller **1001** may apply the secondary rotary output motion to the closure drive gear **2622** which results in the rotation of the knife bar **2580** in a secondary direction. Rotation of the knife bar **2580** in the secondary direction results in the rotation of the closure drive nut **2560** in a secondary direction. As the closure drive nut **2560** rotates in the secondary direction, the closure tube **2550** moves in the proximal direction "PD" to the open position.

FIGS. **56-61**B illustrate yet another surgical tool **2700** that may be effectively employed in connection with the robotic system **1000**. In various forms, the surgical tool **2700** includes a surgical end effector **2712** that includes a "first portion" in the form of an elongated channel **2722** and a "second movable portion" in on form comprising a pivotally translatable clamping member, such as an anvil **2724**, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector **2712**. As shown in the illustrated embodiment, the surgical end effector **2712** may include, in addition to the previously-mentioned channel **2722** and anvil **2724**, a "third movable portion" in the form of a cutting instrument **2732**, a sled (not shown), and a surgical staple cartridge **2734** that is removably seated in the elongated channel **2722**. The cutting instrument **2732** may be, for example, a knife. The anvil **2724** may be pivotably opened and closed at a pivot point **2725** connected to the proximal end of the elongated channel **2722**. The anvil **2724** may also include a tab **2727** at its proximal end that interfaces with a component of the mechanical closure system (described further below) to open and close the anvil **2724**. When actuated, the knife **2732** and sled to travel longitudinally along the elongated channel **2722**, thereby cutting tissue clamped within the surgical end effector **2712**. The movement of the sled along the elongated channel **2722** causes the staples of the surgical staple cartridge **2734** to be driven through the severed tissue and against the closed anvil **2724**, which turns the staples to fasten the severed tissue. In one form, the elongated channel **2722** and the anvil **2724** may be made of an electrically conductive material (such as metal) so that they may serve as part of the antenna that communicates with sensor(s) in the surgical end effector, as described above. The surgical staple cartridge **2734** could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge **2734**, as described above.

It should be noted that although the embodiments of the surgical tool **2500** described herein employ a surgical end effector **2712** that staples the severed tissue, in other embodiments different techniques for fastening or sealing the severed tissue may be used. For example, end effectors that use RF energy or adhesives to fasten the severed tissue may also be used. U.S. Pat. No. 5,709,680, entitled "Electrosurgical Hemostatic Device" to Yates et al., and U.S. Pat. No. 5,688, 270, entitled "Electrosurgical Hemostatic Device With Recessed And/Or Offset Electrodes" to Yates et al., which are incorporated herein by reference, discloses cutting instruments that use RF energy to fasten the severed tissue. U.S. patent application Ser. No. 11/267,811 to Morgan et al., now U.S. Pat. No. 7,673,783, and U.S. patent application Ser. No. 11/267,383 to Shelton et al., now U.S. Pat. 7,607,557, which are also incorporated herein by reference, disclose cutting instruments that use adhesives to fasten the severed tissue. Accordingly, although the description herein refers to cutting/stapling operations and the like, it should be recognized that this is an exemplary embodiment and is not meant to be limiting. Other tissue-fastening techniques may also be used.

In the illustrated embodiment, the elongated channel **2722** of the surgical end effector **2712** is coupled to an elongated shaft assembly **2708** that is coupled to a tool mounting portion **2900**. Although not shown, the elongated shaft assembly **2708** may include an articulation joint to permit the surgical end effector **2712** to be selectively articulated about an axis that is substantially transverse to the tool axis LT-LT. In at least one embodiment, the elongated shaft assembly **2708** comprises a hollow spine tube **2740** that is non-movably coupled to a tool mounting plate **2902** of the tool mounting portion **2900**. As can be seen in FIGS. **57** and **58**, the proximal end **2723** of the elongated channel **2722** comprises a hollow tubular structure that is attached to the spine tube **2740** by means of a mounting collar **2790**. A cross-sectional view of the mounting collar **2790** is shown in FIG. **59**. In various embodiments, the mounting collar **2790** has a proximal flanged end **2791** that is configured for attachment to the distal end of the spine tube **2740**. In at least one embodiment, for example, the proximal flanged end **2791** of the mounting collar **2790** is welded or glued to the distal end of the spine tube **2740**. As can be further seen in FIGS. **57** and **58**, the mounting collar **2790** further has a mounting hub portion **2792** that is sized to receive the proximal end **2723** of the elongated channel **2722** thereon. The proximal end **2723** of the elongated channel **2722** is non-movably attached to the mounting hub portion **2792** by, for example, welding, adhesive, etc.

As can be further seen in FIGS. **57** and **58**, the surgical tool **2700** further includes an axially movable actuation member in the form of a closure tube **2750** that is constrained to move axially relative to the elongated channel **2722**. The closure tube **2750** has a proximal end **2752** that has an internal thread **2754** formed therein that is in threaded engagement with a rotatably movable portion in the form of a closure drive nut **2760**. More specifically, the closure drive nut **2760** has a proximal end portion **2762** that is rotatably supported relative to the elongated channel **2722** and the spine tube **2740**. For assembly purposes, the proximal end portion **2762** is threadably attached to a retention ring **2770**. The retention ring **2770** is received in a groove **2729** formed between a shoulder **2727** on the proximal end **2723** of the channel **2722** and the mounting hub **2729** of the mounting collar **2790**. Such arrangement serves to rotatably support the closure drive nut **2760** within the channel **2722**. Rotation of the closure drive nut **2760** will cause the closure tube **2750** to move axially as represented by arrow "D" in FIG. **57**.

Extending through the spine tube **2740**, the mounting collar **2790**, and the closure drive nut **2760** is a drive member, which in at least one embodiment, comprises a knife bar **2780** that has a distal end portion **2782** that is coupled to the cutting instrument **2732**. As can be seen in FIGS. **57** and **58**, the mounting collar **2790** has a passage **2793** therethrough for permitting the knife bar **2780** to slidably pass therethrough. Similarly, the closure drive nut **2760** has a slot **2764** therein through which the knife bar **2780** can slidably extend. Such arrangement permits the knife bar **2780** to move axially relative to the closure drive nut **2760**.

Actuation of the anvil **2724** is controlled by a rotary driven closure shaft **2800**. As can be seen in FIGS. **57** and **58**, a distal end portion **2802** of the closure drive shaft **2800** extends through a passage **2794** in the mounting collar **2790** and a closure gear **2804** is attached thereto. The closure gear **2804** is configured for driving engagement with the inner surface **2761** of the closure drive nut **2760**. Thus, rotation of the closure shaft **2800** will also result in the rotation of the closure drive nut **2760**. The axial direction in which the closure tube **2750** moves ultimately depends upon the direction in which the closure shaft **2800** and the closure drive nut **2760** are rotated. For example, in response to one rotary closure motion received from the robotic system **1000**, the closure tube **2750** will be driven in the distal direction "DD". As the closure tube **2750** is driven distally, the opening **2745** will engage the tab **2727** on the anvil **2724** and cause the anvil **2724** to pivot to a closed position. Upon application of an opening rotary motion from the robotic system **1000**, the closure tube **2750** will be driven in the proximal direction "PD" and pivot the anvil **2724** to the open position. In various embodiments, a spring (not shown) may be employed to bias the anvil **2724** to the open position (FIG. **57**).

In use, it may be desirable to rotate the surgical end effector **2712** about the longitudinal tool axis LT-LT. In at least one embodiment, the tool mounting portion **2900** is configured to receive a corresponding first rotary output motion from the robotic system **1000** for rotating the elongated shaft assembly **2708** about the tool axis LT-LT. As can be seen in FIG. **61**, a proximal end **2742** of the hollow spine tube **2740** is rotatably supported within a cradle arrangement **2903** and a bearing assembly **2904** that are attached to a tool mounting plate **2902** of the tool mounting portion **2900**. A rotation gear **2744** is formed on or attached to the proximal end **2742** of the spine tube **2740** for meshing engagement with a rotation drive assembly **2910** that is operably supported on the tool mounting plate **2902**. In at least one embodiment, a rotation drive gear **2912** is coupled to a corresponding first one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **2602** when the tool mounting portion **2600** is coupled to the tool holder **1270**. See FIGS. **34** and **61**. The rotation drive assembly **2910** further comprises a rotary driven gear **2914** that is rotatably supported on the tool mounting plate **2902** in meshing engagement with the rotation gear **2744** and the rotation drive gear **2912**. Application of a first rotary control motion from the robotic system **1000** through the tool holder **1270** and the adapter **1240** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **2912** by virtue of being operably coupled thereto. Rotation of the rotation drive gear **2912** ultimately results in the rotation of the elongated shaft assembly **2708** (and the end effector **2712**) about the longitudinal tool axis LT-LT (primary rotary motion).

Closure of the anvil **2724** relative to the staple cartridge **2734** is accomplished by axially moving the closure tube **2750** in the distal direction "DD". Axial movement of the closure tube **2750** in the distal direction "DD" is accomplished by applying a rotary control motion to the closure drive nut **2760**. In various embodiments, the closure drive nut **2760** is rotated by applying a rotary output motion to the closure drive shaft **2800**. As can be seen in FIG. **61**, a proximal end portion **2806** of the closure drive shaft **2800** has a driven gear **2808** thereon that is in meshing engagement with a closure drive assembly **2920**. In various embodiments, the closure drive system **2920** includes a closure drive gear **2922** that is coupled to a corresponding second one of the driven rotational bodies or elements **1304** on the adapter side of the tool mounting plate **2462** when the tool mounting portion **2900** is coupled to the tool holder **1270**. See FIGS. **34** and **61**. The closure drive gear **2922** is supported in meshing engagement with a closure gear train, generally depicted as **2923**. In at least one form, the closure gear rain **2923** comprises a first driven closure gear **2924** that is rotatably supported on the tool mounting plate **2902**. The first closure driven gear **2924** is attached to a second closure driven gear **2926** by a drive shaft **2928**. The second closure driven gear **2926** is in meshing engagement with a planetary gear assembly **2930**. In various embodiments, the planetary gear assembly **2930** includes a driven planetary closure gear **2932** that is rotatably supported within the bearing assembly **2904** that is mounted on tool mounting plate **2902**. As can be seen in FIGS. **61** and **61**B, the proximal end portion **2806** of the closure drive shaft **2800** is rotatably supported within the proximal end portion **2742** of the spine tube **2740** such that the driven gear **2808** is in meshing engagement with central gear teeth **2934** formed on the planetary gear **2932**. As can also be seen in FIG. **61**A, two additional support gears **2936** are attached to or rotatably supported relative to the proximal end portion **2742** of the spine tube **2740** to provide bearing support thereto. Such arrangement with the planetary gear assembly **2930** serves to accommodate rotation of the spine shaft **2740** by the rotation drive assembly **2910** while permitting the closure driven gear **2808** to remain in meshing engagement with the closure drive system **2920**. In addition, rotation of the closure drive gear **2922** in a first direction will ultimately result in the rotation of the closure drive shaft **2800** and closure drive nut **2760** which will ultimately result in the closure of the anvil **2724** as described above. Conversely, rotation of the closure drive gear **2922** in a second opposite direction will ultimately result in the rotation of the closure drive nut **2760** in an opposite direction which results in the opening of the anvil **2724**.

As can be seen in FIG. **61**, the proximal end **2784** of the knife bar **2780** has a threaded shaft portion **2786** attached thereto which is in driving engagement with a knife drive assembly **2940**. In various embodiments, the threaded shaft portion **2786** is rotatably supported by a bearing **2906** attached to the tool mounting plate **2902**. Such arrangement permits the threaded shaft portion **2786** to rotate and move axially relative to the tool mounting plate **2902**. The knife bar **2780** is axially advanced in the distal and proximal directions by the knife drive assembly **2940**. One form of the knife drive assembly **2940** comprises a rotary drive gear **2942** that is coupled to a corresponding third one of the rotatable bodies, driven discs or elements **1304** on the adapter side of the tool mounting plate **2902** when the tool mounting portion **2900** is coupled to the tool holder **1270**. See FIGS. **34** and **61**. The rotary drive gear **2942** is in meshing engagement with a knife gear train, generally depicted as **2943**. In various embodiments, the knife gear train **2943** comprises a first rotary driven gear assembly **2944** that is rotatably supported on the tool mounting plate **2902**. The first rotary driven gear assembly **2944** is in meshing engagement with a third rotary driven gear assembly **2946** that is rotatably supported on the tool mounting plate **2902** and which is in meshing engagement with a fourth rotary driven gear assembly **2948** that is in meshing engagement with the threaded portion **2786** of the knife bar **2780**. Rotation of the rotary drive gear **2942** in one direction will result in the axial advancement of the knife bar **2780** in the distal direction "DD". Conversely, rotation of the rotary drive gear **2942** in an opposite direction will cause the knife bar **2780** to move in the proximal direction. Tool **2700** may otherwise be used as described above.

FIGS. **62** and **63** illustrate a surgical tool embodiment **2700** that is substantially identical to tool **2700** that was described in detail above. However tool **2700'** includes a pressure sensor **2950** that is configured to provide feedback to the robotic controller **1001** concerning the amount of clamping pressure experienced by the anvil **2724**. In various embodiments, for example, the pressure sensor may comprise a spring biased contact switch. For a continuous signal, it would use either a cantilever beam with a strain gage on it or a dome button top with a strain gage on the inside. Another version may comprise an off switch that contacts only at a known desired load. Such arrangement would include a dome on the based wherein the dome is one electrical pole and the base is the other electrical pole. Such arrangement permits the robotic controller **1001** to adjust the amount of clamping pressure being applied to the tissue within the surgical end effector **2712** by adjusting the amount of closing pressure applied to the anvil **2724**. Those of ordinary skill in the art will understand that such pressure sensor arrangement may be effectively employed with several of the surgical tool embodiments described herein as well as their equivalent structures.

FIG. **64** illustrates a portion of another surgical tool **3000** that may be effectively used in connection with a robotic system **1000**. The surgical tool **3003** employs on-board motor(s) for powering various components of a surgical end effector cutting instrument. In at least one non-limiting embodiment for example, the surgical tool **3000** includes a surgical end effector in the form of an endocutter (not shown) that has an anvil (not shown) and surgical staple cartridge arrangement (not shown) of the types and constructions described above. The surgical tool **3000** also includes an elongated shaft (not shown) and anvil closure arrangement (not shown) of the types described above. Thus, this portion of the Detailed Description will not repeat the description of those components beyond that which is necessary to appreciate the unique and novel attributes of the various embodiments of surgical tool **3000**.

In the depicted embodiment, the end effector includes a cutting instrument **3002** that is coupled to a knife bar **3003**. As can be seen in FIG. **64**, the surgical tool **3000** includes a tool mounting portion **3010** that includes a tool mounting plate **3012** that is configured to mountingly interface with the adaptor portion **1240'** which is coupled to the robotic system **1000** in the various manners described above. The tool mounting portion **3010** is configured to operably support a transmission arrangement **3013** thereon. In at least one embodiment, the adaptor portion **1240'** may be identical to the adaptor portion **1240** described in detail above without the powered rotation bodies and disc members employed by adapter **1240**. In other embodiments, the adaptor portion **1240'** may be identical to adaptor portion **1240**. Still other modifications which are considered to be within the spirit and scope of the various forms of the present invention may employ one or more of the mechanical motions (i.e., rotary motion(s)) from the tool holder portion **1270** (as described hereinabove) to power/actuate the transmission arrangement **3013** while also employing one or more motors within the tool mounting portion **3010** to power one or more other components of the surgical end effector. In addition, while the end effector of the depicted embodiment comprises an endocutter, those of ordinary skill in the art will understand that the unique and novel attributes of the depicted embodiment may be effectively employed in connection with other types of surgical end effectors without departing from the spirit and scope of various forms of the present invention.

In various embodiments, the tool mounting plate **3012** is configured to at least house a first firing motor **3011** for supplying firing and retraction motions to the knife bar **3003** which is coupled to or otherwise operably interfaces with the cutting instrument **3002**. The tool mounting plate **3012** has an array of electrical connecting pins **3014** which are configured to interface with the slots **1258** (FIG. **33**) in the adapter **1240'**. Such arrangement permits the controller **1001** of the robotic system **1000** to provide control signals to the electronic control circuit **3020** of the surgical tool **3000**. While the interface is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

Control circuit **3020** is shown in schematic form in FIG. **64**. In one form or embodiment, the control circuit **3020** includes a power supply in the form of a battery **3022** that is coupled to an on-off solenoid powered switch **3024**. Control circuit **3020** further includes an on/off firing solenoid **3026** that is coupled to a double pole switch **3028** for controlling the rotational direction of the motor **3011**. Thus, when the controller **1001** of the robotic system **1000** supplies an appropriate control signal, switch **3024** will permit battery **3022** to supply power to the double pole switch **3028**. The controller **1001** of the robotic system **1000** will also supply an appropriate signal to the double pole switch **3028** to supply power to the motor **3011**. When it is desired to fire the surgical end effector (i.e., drive the cutting instrument **3002** distally through tissue clamped in the surgical end effector, the double pole switch **3028** will be in a first position. When it is desired to retract the cutting instrument **3002** to the starting position, the double pole switch **3028** will be moved to the second position by the controller **1001**.

Various embodiments of the surgical tool **3000** also employ a gear box **3030** that is sized, in cooperation with a firing gear train **3031** that, in at least one non-limiting embodiment, comprises a firing drive gear **3032** that is in meshing engagement with a firing driven gear **3034** for generating a desired amount of driving force necessary to drive the cutting instrument **3002** through tissue and to drive and form staples in the various manners described herein. In the embodiment depicted in FIG. **61**, the driven gear **3034** is coupled to a screw shaft **3036** that is in threaded engagement with a screw nut arrangement **3038** that is constrained to move axially (represented by arrow "D"). The screw nut arrangement **3038** is attached to the firing bar **3003**. Thus, by rotating the screw shaft **3036** in a first direction, the cutting instrument **3002** is driven in the distal direction "DD" and rotating the screw shaft in an opposite second direction, the cutting instrument **3002** may be retracted in the proximal direction "PD".

FIG. **65** illustrates a portion of another surgical tool **3000'** that is substantially identical to tool **3000** described above, except that the driven gear **3034** is attached to a drive shaft **3040**. The drive shaft **3040** is attached to a second driver gear **3042** that is in meshing engagement with a third driven gear **3044** that is in meshing engagement with a screw **3046** coupled to the firing bar **3003**.

FIG. **66** illustrates another surgical tool **3200** that may be effectively used in connection with a robotic system **1000**. In this embodiment, the surgical tool **3200** includes a surgical end effector **3212** that in one non-limiting form, comprises a component portion that is selectively movable between first and second positions relative to at least one other end effector component portion. As will be discussed in further detail below, the surgical tool **3200** employs on-board motors for powering various components of a transmission arrangement **3305**. The surgical end effector **3212** includes an elongated channel **3222** that operably supports a surgical staple cartridge **3234**. The elongated channel **3222** has a proximal end **3223** that slidably extends into a hollow elongated shaft assembly **3208** that is coupled to a tool mounting portion **3300**. In addition, the surgical end effector **3212** includes an anvil **3224** that is pivotally coupled to the elongated channel **3222** by a pair of trunnions **3225** that are received within corresponding openings **3229** in the elongated channel **3222**. A distal end portion **3209** of the shaft assembly **3208** includes an opening **3245** into which a tab **3227** on the anvil **3224** is inserted in order to open the anvil **3224** as the elongated channel **3222** is moved axially in the proximal direction "PD" relative to the distal end portion **3209** of the shaft assembly **3208**. In various embodiments, a spring (not shown) may be employed to bias the anvil **3224** to the open position.

As indicated above, the surgical tool **3200** includes a tool mounting portion **3300** that includes a tool mounting plate **3302** that is configured to operably support the transmission arrangement **3305** and to mountingly interface with the adaptor portion **1240'** which is coupled to the robotic system **1000** in the various manners described above. In at least one embodiment, the adaptor portion **1240'** may be identical to the adaptor portion **1240** described in detail above without the powered disc members employed by adapter **1240**. In other embodiments, the adaptor portion **1240'** may be identical to adaptor portion **1240**. However, in such embodiments, because the various components of the surgical end effector **3212** are all powered by motor(s) in the tool mounting portion **3300**, the surgical tool **3200** will not employ or require any of the mechanical (i.e., non-electrical) actuation motions from the tool holder portion **1270** to power the surgical end effector **3200** components. Still other modifications which are considered to be within the spirit and scope of the various forms of the present invention may employ one or more of the mechanical motions from the tool holder portion **1270** (as described hereinabove) to power/actuate one or more of the surgical end effector components while also employing one or more motors within the tool mounting portion to power one or more other components of the surgical end effector.

In various embodiments, the tool mounting plate **3302** is configured to support a first firing motor **3310** for supplying firing and retraction motions to the transmission arrangement **3305** to drive a knife bar **3335** that is coupled to a cutting instrument **3332** of the type described above. As can be seen in FIG. **66**, the tool mounting plate **3212** has an array of electrical connecting pins **3014** which are configured to interface with the slots **1258** (FIG. **33**) in the adapter **1240'**. Such arrangement permits the controller **1001** of the robotic system **1000** to provide control signals to the electronic control circuits **3320**, **3340** of the surgical tool **3200**. While the interface is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

In one form or embodiment, the first control circuit **3320** includes a first power supply in the form of a first battery **3322** that is coupled to a first on-off solenoid powered switch **3324**. The first firing control circuit **3320** further includes a first on/off firing solenoid **3326** that is coupled to a first double pole switch **3328** for controlling the rotational direction of the first firing motor **3310**. Thus, when the robotic controller **1001** supplies an appropriate control signal, the first switch **3324** will permit the first battery **3322** to supply power to the first double pole switch **3328**. The robotic controller **1001** will also supply an appropriate signal to the first double pole switch **3328** to supply power to the first firing motor **3310**. When it is desired to fire the surgical end effector (i.e., drive the cutting instrument **3232** distally through tissue clamped in the surgical end effector **3212**, the first switch **3328** will be positioned in a first position by the robotic controller **1001**. When it is desired to retract the cutting instrument **3232** to the starting position, the robotic controller **1001** will send the appropriate control signal to move the first switch **3328** to the second position.

Various embodiments of the surgical tool **3200** also employ a first gear box **3330** that is sized, in cooperation with a firing drive gear **3332** coupled thereto that operably interfaces with a firing gear train **3333**. In at least one non-limiting embodiment, the firing gear train **333** comprises a firing driven gear **3334** that is in meshing engagement with drive gear **3332**, for generating a desired amount of driving force necessary to drive the cutting instrument **3232** through tissue and to drive and form staples in the various manners described herein. In the embodiment depicted in FIG. **66**, the driven gear **3334** is coupled to a drive shaft **3335** that has a second driven gear **3336** coupled thereto. The second driven gear **3336** is supported in meshing engagement with a third driven gear **3337** that is in meshing engagement with a fourth driven gear **3338**. The fourth driven gear **3338** is in meshing engagement with a threaded proximal portion **3339** of the knife bar **3235** that is constrained to move axially. Thus, by rotating the drive shaft **3335** in a first direction, the cutting instrument **3232** is driven in the distal direction "DD" and rotating the drive shaft **3335** in an opposite second direction, the cutting instrument **3232** may be retracted in the proximal direction "PD".

As indicated above, the opening and closing of the anvil **3224** is controlled by axially moving the elongated channel **3222** relative to the elongated shaft assembly **3208**. The axial movement of the elongated channel **3222** is controlled by a closure control system **3339**. In various embodiments, the closure control system **3339** includes a closure shaft **3340** which has a hollow threaded end portion **3341** that threadably engages a threaded closure rod **3342**. The threaded end portion **3341** is rotatably supported in a spine shaft **3343** that operably interfaces with the tool mounting portion **3300** and extends through a portion of the shaft assembly **3208** as shown. The closure system **3339** further comprises a closure control circuit **3350** that includes a second power supply in the form of a second battery **3352** that is coupled to a second on-off solenoid powered switch **3354**. Closure control circuit **3350** further includes a second on/off firing solenoid **3356** that is coupled to a second double pole switch **3358** for controlling the rotation of a second closure motor **3360**. Thus, when the robotic controller **1001** supplies an appropriate control signal, the second switch **3354** will permit the second battery **3352** to supply power to the second double pole switch **3354**. The robotic controller **1001** will also supply an appropriate signal to the second double pole switch **3358** to supply power to the second motor **3360**. When it is desired to close the anvil **3224**, the second switch **3348** will be in a first position. When it is desired to open the anvil **3224**, the second switch **3348** will be moved to a second position.

Various embodiments of tool mounting portion **3300** also employ a second gear box **3362** that is coupled to a closure drive gear **3364**. The closure drive gear **3364** is in meshing engagement with a closure gear train **3363**. In various non-limiting forms, the closure gear train **3363** includes a closure driven gear **3365** that is attached to a closure drive shaft **3366**. Also attached to the closure drive shaft **3366** is a closure drive gear **3367** that is in meshing engagement with a closure shaft gear **3360** attached to the closure shaft **3340**. FIG. **66** depicts the end effector **3212** in the open position. As indicated above, when the threaded closure rod **3342** is in the position depicted in FIG. **66**, a spring (not shown) biases the anvil **3224** to the open position. When it is desired to close the anvil **3224**, the robotic controller **1001** will activate the second motor **3360** to rotate the closure shaft **3340** to draw the threaded closure rod **3342** and the channel **3222** in the proximal direction 'PD'. As the anvil **3224** contacts the distal end portion **3209** of the shaft **3208**, the anvil **3224** is pivoted to the closed position.

A method of operating the surgical tool **3200** will now be described. Once the tool mounting portion **3302** has be operably coupled to the tool holder **1270** of the robotic system **1000**, the robotic system **1000** can orient the end effector **3212** in position adjacent the target tissue to be cut and stapled. If the anvil **3224** is not already in the open position, the robotic controller **1001** may activate the second closure motor **3360** to drive the channel **3222** in the distal direction to the position depicted in FIG. **66**. Once the robotic controller **1001** determines that the surgical end effector **3212** is in the open position by sensor(s) in the and effector and/or the tool mounting portion **3300**, the robotic controller **1001** may provide the surgeon with a signal to inform the surgeon that the anvil **3224** may then be closed. Once the target tissue is positioned between the open anvil **3224** and the surgical staple cartridge **3234**, the surgeon may then commence the closure process by activating the robotic controller **1001** to apply a closure control signal to the second closure motor **3360**. The second closure motor **3360** applies a rotary motion to the closure shaft **3340** to draw the channel **3222** in the proximal direction "PD" until the anvil **3224** has been pivoted to the closed position. Once the robotic controller **1001** determines that the anvil **3224** has been moved to the closed position by sensor(s) in the surgical end effector **3212** and/or in the tool mounting portion **3300** that are in communication with the robotic control system, the motor **3360** may be deactivated. Thereafter, the firing process may be commenced either manually by the surgeon activating a trigger, button, etc. on the controller **1001** or the controller **1001** may automatically commence the firing process.

To commence the firing process, the robotic controller **1001** activates the firing motor **3310** to drive the firing bar **3235** and the cutting instrument **3232** in the distal direction "DD". Once robotic controller **1001** has determined that the cutting instrument **3232** has moved to the ending position within the surgical staple cartridge **3234** by means of sensors in the surgical end effector **3212** and/or the motor drive portion **3300**, the robotic controller **1001** may provide the surgeon with an indication signal. Thereafter the surgeon may manually activate the first motor **3310** to retract the cutting instrument **3232** to the starting position or the robotic controller **1001** may automatically activate the first motor **3310** to retract the cutting element **3232**.

The embodiment depicted in FIG. **66** does not include an articulation joint. FIGS. **67** and **68** illustrate surgical tools **3200'** and **3200"** that have end effectors **3212'**, **3212"**, respectively that may be employed with an elongated shaft embodiment that has an articulation joint of the various types disclosed herein. For example, as can be seen in FIG. **64**, a threaded closure shaft **3342** is coupled to the proximal end **3223** of the elongated channel **3222** by a flexible cable or other flexible member **3345**. The location of an articulation joint (not shown) within the elongated shaft assembly **3208** will coincide with the flexible member **3345** to enable the flexible member **3345** to accommodate such articulation. In addition, in the above-described embodiment, the flexible member **33345** is rotatably affixed to the proximal end portion **3223** of the elongated channel **3222** to enable the flexible member **3345** to rotate relative thereto to prevent the flexible member **3229** from "winding up" relative to the channel **3222**. Although not shown, the cutting element may be driven in one of the above described manners by a knife bar that can also accommodate articulation of the elongated shaft assembly. FIG. **68** depicts a surgical end effector **3212"** that is substantially identical to the surgical end effector **3212** described above, except that the threaded closure rod **3342** is attached to a closure nut **3347** that is constrained to only move axially within the elongated shaft assembly **3208**. The flexible member **3345** is attached to the closure nut **3347**. Such arrangement also prevents the threaded closure rod **3342** from winding-up the flexible member **3345**. A flexible knife bar **3235'** may be employed to facilitate articulation of the surgical end effector **3212"**.

The surgical tools **3200**, **3200'**, and **3200"** described above may also employ anyone of the cutting instrument embodiments described herein. As described above, the anvil of each of the end effectors of these tools is closed by drawing the elongated channel into contact with the distal end of the elongated shaft assembly. Thus, once the target tissue has been located between the staple cartridge **3234** and the anvil **3224**, the robotic controller **1001** can start to draw the channel **3222** inward into the shaft assembly **3208**. In various embodiments, however, to prevent the end effector **3212**, **3212'**, **3212"** from moving the target tissue with the end effector during this closing process, the controller **1001** may simultaneously move the tool holder and ultimately the tool such to compensate for the movement of the elongated channel **3222** so that, in effect, the target tissue is clamped between the anvil and the elongated channel without being otherwise moved.

FIGS. **69-71** depict another surgical tool embodiment **3201** that is substantially identical to surgical tool **3200"** described above, except for the differences discussed below. In this embodiment, the threaded closure rod **3342'** has variable pitched grooves. More specifically, as can be seen in FIG. **70**, the closure rod **3342'** has a distal groove section **3380** and a proximal groove section **3382**. The distal and proximal groove sections **3380**, **3382** are configured for engagement with a lug **3390** supported within the hollow threaded end portion **3341'**. As can be seen in FIG. **70**, the distal groove section **3380** has a finer pitch than the groove section **3382**. Thus, such variable pitch arrangement permits the elongated channel **3222** to be drawn into the shaft **3208** at a first speed or rate by virtue of the engagement between the lug **3390** and the proximal groove segment **3382**. When the lug **3390** engages the distal groove segment, the channel **3222** will be drawn into the shaft **3208** at a second speed or rate. Because the proximal groove segment **3382** is coarser than the distal groove segment **3380**, the first speed will be greater than the second speed. Such arrangement serves to speed up the initial closing of the end effector for tissue manipulation and then after the tissue has been properly positioned therein, generate the amount of closure forces to properly clamp the tissue for cutting and sealing. Thus, the anvil **3234** initially closes fast with a lower force and then applies a higher closing force as the anvil closes more slowly.

The surgical end effector opening and closing motions are employed to enable the user to use the end effector to grasp and manipulate tissue prior to fully clamping it in the desired location for cutting and sealing. The user may, for example, open and close the surgical end effector numerous times during this process to orient the end effector in a proper position which enables the tissue to be held in a desired location. Thus, in at least some embodiments, to produce the high loading for firing, the fine thread may require as many as 5-10 full rotations to generate the necessary load. In some cases, for example, this action could take as long as 2-5 seconds. If it also took an equally long time to open and close the end effector each time during the positioning/tissue manipulation process, just positioning the end effector may take an undesirably long time. If that happens, it is possible that a user may abandon such use of the end effector for use of a conventional grasper device. Use of graspers, etc. may undesirably increase the costs associated with completing the surgical procedure.

The above-described embodiments employ a battery or batteries to power the motors used to drive the end effector components. Activation of the motors is controlled by the robotic system **1000**. In alternative embodiments, the power supply may comprise alternating current "AC" that is supplied to the motors by the robotic system **1000**. That is, the AC power would be supplied from the system powering the robotic system **1000** through the tool holder and adapter. In still other embodiments, a power cord or tether may be attached to the tool mounting portion **3300** to supply the requisite power from a separate source of alternating or direct current.

In use, the controller **1001** may apply an initial rotary motion to the closure shaft **3340** (FIG. **66**) to draw the elongated channel **3222** axially inwardly into the elongated shaft assembly **3208** and move the anvil from a first position to an intermediate position at a first rate that corresponds with the point wherein the distal groove section **3380** transitions to the proximal groove section **3382**. Further application of rotary motion to the closure shaft **3340** will cause the anvil to move from the intermediate position to the closed position relative to the surgical staple cartridge. When in the closed position, the tissue to be cut and stapled is properly clamped between the anvil and the surgical staple cartridge.

FIGS. **72-75** illustrate another surgical tool embodiment **3400** of the present invention. This embodiment includes an elongated shaft assembly **3408** that extends from a tool mounting portion **3500**. The elongated shaft assembly **3408** includes a rotatable proximal closure tube segment **3410** that is rotatably journaled on a proximal spine member **3420** that is rigidly coupled to a tool mounting plate **3502** of the tool mounting portion **3500**. The proximal spine member **3420** has a distal end **3422** that is coupled to an elongated channel portion **3522** of a surgical end effector **3412**. For example, in at least one embodiment, the elongated channel portion **3522** has a distal end portion **3523** that "hookingly engages" the distal end **3422** of the spine member **3420**. The elongated channel **3522** is configured to support a surgical staple cartridge **3534** therein. This embodiment may employ one of the various cutting instrument embodiments disclosed herein to sever tissue that is clamped in the surgical end effector **3412** and fire the staples in the staple cartridge **3534** into the severed tissue.

Surgical end effector **3412** has an anvil **3524** that is pivotally coupled to the elongated channel **3522** by a pair of trunnions **3525** that are received in corresponding openings **3529** in the elongated channel **3522**. The anvil **3524** is moved between the open (FIG. **72**) and closed positions (FIGS. **73-75**) by a distal closure tube segment **3430**. A distal end portion **3432** of the distal closure tube segment **3430** includes an opening **3445** into which a tab **3527** on the anvil **3524** is inserted in order to open and close the anvil **3524** as the distal closure tube segment **3430** moves axially relative thereto. In various embodiments, the opening **3445** is shaped such that as the closure tube segment **3430** is moved in the proximal direction, the closure tube segment **3430** causes the anvil **3524** to pivot to an open position. In addition or in the alternative, a spring (not shown) may be employed to bias the anvil **3524** to the open position.

As can be seen in FIGS. **72-75**, the distal closure tube segment **3430** includes a lug **3442** that extends from its distal end **3440** into threaded engagement with a variable pitch groove/thread **3414** formed in the distal end **3412** of the rotatable proximal closure tube segment **3410**. The variable pitch groove/thread **3414** has a distal section **3416** and a proximal section **3418**. The pitch of the distal groove/thread section **3416** is finer than the pitch of the proximal groove/thread section **3418**. As can also be seen in FIGS. **72-75**, the distal closure tube segment **3430** is constrained for axial movement relative to the spine member **3420** by an axial retainer pin **3450** that is received in an axial slot **3424** in the distal end of the spine member **3420**.

As indicated above, the anvil **2524** is open and closed by rotating the proximal closure tube segment **3410**. The variable pitch thread arrangement permits the distal closure tube segment **3430** to be driven in the distal direction "DD" at a first speed or rate by virtue of the engagement between the lug **3442** and the proximal groove/thread section **3418**. When the lug **3442** engages the distal groove/thread section **3416**, the distal closure tube segment **3430** will be driven in the distal direction at a second speed or rate. Because the proximal groove/thread section **3418** is coarser than the distal groove/thread segment **3416**, the first speed will be greater than the second speed.

In at least one embodiment, the tool mounting portion **3500** is configured to receive a corresponding first rotary motion from the robotic controller **1001** and convert that first rotary motion to a primary rotary motion for rotating the rotatable proximal closure tube segment **3410** about a longitudinal tool axis LT-LT. As can be seen in FIG. **76**, a proximal end **3460** of the proximal closure tube segment **3410** is rotatably supported within a cradle arrangement **3504** attached to a tool mounting plate **3502** of the tool mounting portion **3500**. A rotation gear **3462** is formed on or attached to the proximal end **3460** of the closure tube segment **3410** for meshing engagement with a rotation drive assembly **3470** that is operably supported on the tool mounting plate **3502**. In at least one embodiment, a rotation drive gear **3472** is coupled to a corresponding first one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **3502** when the tool mounting portion **3500** is coupled to the tool holder **1270**. See FIGS. **34** and **76**. The rotation drive assembly **3470** further comprises a rotary driven gear **3474** that is rotatably supported on the tool mounting plate **3502** in meshing engagement with the rotation gear **3462** and the rotation drive gear **3472**. Application of a first rotary control motion from the robotic controller **1001** through the tool holder **1270** and the adapter **1240** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **3472** by virtue of being operably coupled thereto. Rotation of the rotation drive gear **3472** ultimately results in the rotation of the closure tube segment **3410** to open and close the anvil **3524** as described above.

As indicated above, the surgical end effector **3412** employs a cutting instrument of the type and constructions described above. FIG. **76** illustrates one form of knife drive assembly **3480** for axially advancing a knife bar **3492** that is attached to such cutting instrument. One form of the knife drive assembly **3480** comprises a rotary drive gear **3482** that is coupled to a corresponding third one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **3502** when the tool drive portion **3500** is coupled to the tool holder **1270**. See FIGS. **34** and **76**. The knife drive assembly **3480** further comprises a first rotary driven gear assembly **3484** that is rotatably supported on the tool mounting plate **5200**. The first rotary driven gear assembly **3484** is in meshing engagement with a third rotary driven gear assembly **3486** that is rotatably supported on the tool mounting plate **3502** and which is in meshing engagement with a fourth rotary driven gear assembly **3488** that is in meshing engagement with a threaded portion **3494** of drive shaft assembly **3490** that is coupled to the knife bar **3492**. Rotation of the rotary drive gear **3482** in a second rotary direction will result in the axial advancement of the drive shaft assembly **3490** and knife bar **3492** in the distal direction "DD". Conversely, rotation of the rotary drive gear **3482** in a secondary rotary direction (opposite to the second rotary direction) will cause the drive shaft assembly **3490** and the knife bar **3492** to move in the proximal direction.

FIGS. **77-86** illustrate another surgical tool **3600** embodiment of the present invention that may be employed in connection with a robotic system **1000**. As can be seen in FIG. **77**, the tool **3600** includes an end effector in the form of a disposable loading unit **3612**. Various forms of disposable loading units that may be employed in connection with tool **3600** are disclosed, for example, in U.S. Patent Application Publication No. US 2009/0206131 A1, entitled "End Effector Arrangements For a Surgical Cutting and Stapling Instrument", the disclosure of which is herein incorporated by reference in its entirety.

In at least one form, the disposable loading unit **3612** includes an anvil assembly **3620** that is supported for pivotal travel relative to a carrier **3630** that operably supports a staple cartridge **3640** therein. A mounting assembly **3650** is pivotally coupled to the cartridge carrier **3630** to enable the carrier **3630** to pivot about an articulation axis AA-AA relative to a longitudinal tool axis LT-LT. Referring to FIG. **82**, mounting assembly **3650** includes upper and lower mounting portions **3652** and **3654**. Each mounting portion includes a threaded bore **3656** on each side thereof dimensioned to receive threaded bolts (not shown) for securing the proximal end of carrier **3630** thereto. A pair of centrally located pivot members **3658** extends between upper and lower mounting portions via a pair of coupling members **3660** which engage a distal end of a housing portion **3662**. Coupling members **3660** each include an interlocking proximal portion **3664** configured to be received in grooves **3666** formed in the proximal end of housing portion **3662** to retain mounting assembly **3650** and housing portion **3662** in a longitudinally fixed position in relation thereto.

In various forms, housing portion **3662** of disposable loading unit **3614** includes an upper housing half **3670** and a lower housing half **3672** contained within an outer casing **3674**. The proximal end of housing half **3670** includes engagement nubs **3676** for releasably engaging an elongated shaft **3700** and an insertion tip **3678**. Nubs **3676** form a bayonet-type coupling with the distal end of the elongated shaft **3700** which will be discussed in further detail below. Housing halves **3670**, **3672** define a channel **3674** for slidably receiving axial drive assembly **3680**. A second articulation link **3690** is dimensioned to be slidably positioned within a slot **3679** formed between housing halves **3670**, **3672**. A pair of blow out plates **3691** are positioned adjacent the distal end of housing portion **3662** adjacent the distal end of axial drive assembly **3680** to prevent outward bulging of drive assembly **3680** during articulation of carrier **3630**.

In various embodiments, the second articulation link **3690** includes at least one elongated metallic plate. Preferably, two or more metallic plates are stacked to form link **3690**. The proximal end of articulation link **3690** includes a hook portion **3692** configured to engage first articulation link **3710** extending through the elongated shaft **3700**. The distal end of the second articulation link **3690** includes a loop **3694** dimensioned to engage a projection formed on mounting assembly **3650**. The projection is laterally offset from pivot pin **3658** such that linear movement of second articulation link **3690** causes mounting assembly **3650** to pivot about pivot pins **3658** to articulate the carrier **3630**.

In various forms, axial drive assembly **3680** includes an elongated drive beam **3682** including a distal working head **3684** and a proximal engagement section **3685**. Drive beam **3682** may be constructed from a single sheet of material or, preferably, multiple stacked sheets. Engagement section **3685** includes a pair of engagement fingers which are dimensioned and configured to mountingly engage a pair of corresponding retention slots formed in drive member **3686**. Drive member **3686** includes a proximal porthole **3687** configured to receive the distal end **3722** of control rod **2720** (See FIG. **86**) when the proximal end of disposable loading unit **3614** is engaged with elongated shaft **3700** of surgical tool **3600**.

Referring to FIGS. **77** and **84**-**86**, to use the surgical tool **3600**, a disposable loading unit **3612** is first secured to the distal end of elongated shaft **3700**. It will be appreciated that the surgical tool **3600** may include an articulating or a non-articulating disposable loading unit. To secure the disposable loading unit **3612** to the elongated shaft **3700**, the distal end **3722** of control rod **3720** is inserted into insertion tip **3678** of disposable loading unit **3612**, and insertion tip **3678** is slid longitudinally into the distal end of the elongated shaft **3700** in the direction indicated by arrow “A” in FIG. **84** such that hook portion **3692** of second articulation link **3690** slides within a channel **3702** in the elongated shaft **3700**. Nubs **3676** will each be aligned in a respective channel (not shown) in elongated shaft **3700**. When hook portion **3692** engages the proximal wall **3704** of channel **3702**, disposable loading unit **3612** is rotated in the direction indicated by arrow “B” in FIGS. **83** and **84** to move hook portion **3692** of second articulation link **3690** into engagement with finger **3712** of first articulation link **3710**. Nubs **3676** also form a “bayonet-type” coupling within annular channel **3703** in the elongated shaft **3700**. During rotation of loading unit **3612**, nubs **3676** engage cam surface **3732** (FIG. **84**) of block plate **3730** to initially move plate **3730** in the direction indicated by arrow “C” in FIG. **84** to lock engagement member **3734** in recess **3721** of control rod **3720** to prevent longitudinal movement of control rod **3720** during attachment of disposable loading unit **3612**. During the final degree of rotation, nubs **3676** disengage from cam surface **3732** to allow blocking plate **3730** to move in the direction indicated by arrow “D” in FIGS. **83** and **86** from behind engagement member **3734** to once again permit longitudinal movement of control rod **3720**. While the above-described attachment method reflects that the disposable loading unit **3612** is manipulated relative to the elongated shaft **3700**, the person of ordinary skill in the art will appreciate that the disposable loading unit **3612** may be supported in a stationary position and the robotic system **1000** may manipulate the elongated shaft portion **3700** relative to the disposable loading unit **3612** to accomplish the above-described coupling procedure.

FIG. **87** illustrates another disposable loading unit **3612'** that is attachable in a bayonet-type arrangement with the elongated shaft **3700'** that is substantially identical to shaft **3700** except for the differences discussed below. As can be seen in FIG. **87**, the elongated shaft **3700'** has slots **3705** that extend for at least a portion thereof and which are configured to receive nubs **3676** therein. In various embodiments, the disposable loading unit **3612'** includes arms **3677** extending therefrom which, prior to the rotation of disposable loading unit **3612'**, can be aligned, or at least substantially aligned, with nubs **3676** extending from housing portion **3662**. In at least one embodiment, arms **3677** and nubs **3676** can be inserted into slots **3705** in elongated shaft **3700'**, for example, when disposable loading unit **3612'** is inserted into elongated shaft **3700'**. When disposable loading unit **3612'** is rotated, arms **3677** can be sufficiently confined within slots **3705** such that slots **3705** can hold them in position, whereas nubs **3676** can be positioned such that they are not confined within slots **3705** and can be rotated relative to arms **3677**. When rotated, the hook portion **3692** of the articulation link **3690** is engaged with the first articulation link **3710** extending through the elongated shaft **3700'**.

Other methods of coupling the disposable loading units to the end of the elongated shaft may be employed. For example, as shown in FIGS. **88** and **89**, disposable loading unit **3612"** can include connector portion **3613** which can be configured to be engaged with connector portion **3740** of the elongated shaft **3700"**. In at least one embodiment, connector portion **3613** can include at least one projection and/or groove which can be mated with at least one projection and/or groove of connector portion **3740**. In at least one such embodiment, the connector portions can include co-operating dovetail portions. In various embodiments, the connector portions can be configured to interlock with one another and prevent, or at least inhibit, distal and/or proximal movement of disposable loading unit **3612"** along axis **3741**. In at least one embodiment, the distal end of the axial drive assembly **3680'** can include aperture **3681** which can be configured to receive projection **3721** extending from control rod **3720'**. In various embodiments, such an arrangement can allow disposable loading unit **3612"** to be assembled to elongated shaft **3700** in a direction which is not collinear with or parallel to axis **3741**. Although not illustrated, axial drive assembly **3680'** and control rod **3720** can include any other suitable arrangement of projections and apertures to operably connect them to each other. Also in this embodiment, the first articulation link **3710** which can be operably engaged with second articulation link **3690**.

As can be seen in FIGS. **77** and **90**, the surgical tool **3600** includes a tool mounting portion **3750**. The tool mounting portion **3750** includes a tool mounting plate **3751** that is configured for attachment to the tool drive assembly **1010**. The tool mounting portion operably supported a transmission arrangement **3752** thereon. In use, it may be desirable to rotate the disposable loading unit **3612** about the longitudinal tool axis defined by the elongated shaft **3700**. In at least one embodiment, the transmission arrangement **3752** includes a rotational transmission assembly **3753** that is configured to receive a corresponding rotary output motion from the tool drive assembly **1010** of the robotic system **1000** and convert that rotary output motion to a rotary control motion for rotating the elongated shaft **3700** (and the disposable loading unit **3612**) about the longitudinal tool axis LT-LT. As can be seen in FIG. **90**, a proximal end **3701** of the elongated shaft **3700** is rotatably supported within a cradle arrangement **3754** that is attached to the tool mounting plate **3751** of the tool mounting portion **3750**. A rotation gear **3755** is formed on or attached to the proximal end **3701** of the elongated shaft **3700** for meshing engagement with a rotation gear assembly **3756** operably supported on the tool mounting plate **3751**. In at least one embodiment, a rotation drive gear **3757** drivingly coupled to a corresponding first one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **3751** when the tool mounting portion **3750** is coupled to the tool drive assembly **1010**. The rotation transmission assembly **3753** further comprises a rotary driven gear **3758** that is rotatably supported on the tool mounting plate **3751** in meshing engagement with the rotation gear **3755** and the rotation drive gear **3757**. Application of a first rotary output motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **3757** by virtue of being operably coupled thereto. Rotation of the rotation drive gear **3757** ultimately results in the rotation of the elongated shaft **3700** (and the disposable loading unit **3612**) about the longitudinal tool axis LT-LT (primary rotary motion).

As can be seen in FIG. **90**, a drive shaft assembly **3760** is coupled to a proximal end of the control rod **2720**. In various embodiments, the control rod **2720** is axially advanced in the distal and proximal directions by a knife/closure drive transmission **3762**. One form of the knife/closure drive assembly **3762** comprises a rotary drive gear **3763** that is coupled to a corresponding second one of the driven rotatable body portions, discs or elements **1304** on the adapter side of the tool mounting plate **3751** when the tool mounting portion **3750** is coupled to the tool holder **1270**. The rotary driven gear **3763** is in meshing driving engagement with a gear train, generally depicted as **3764**. In at least one form, the gear train **3764** further comprises a first rotary driven gear assembly **3765** that is rotatably supported on the tool mounting plate **3751**. The first rotary driven gear assembly **3765** is in meshing engagement with a second rotary driven gear assembly **3766** that is rotatably supported on the tool mounting plate **3751** and which is in meshing engagement with a third rotary driven gear assembly **3767** that is in meshing engagement with a threaded portion **3768** of the drive shaft assembly **3760**. Rotation of the rotary drive gear **3763** in a second rotary direction will result in the axial advancement of the drive shaft assembly **3760** and control rod **2720** in the distal direction "DD". Conversely, rotation of the rotary drive gear **3763** in a secondary rotary direction which is opposite to the second rotary direction will cause the drive shaft assembly **3760** and the control rod **2720** to move in the proximal direction. When the control rod **2720** moves in the distal direction, it drives the drive beam **3682** and the working head **3684** thereof distally through the surgical staple cartridge **3640**. As the working head **3684** is driven distally, it operably engages the anvil **3620** to pivot it to a closed position.

The cartridge carrier **3630** may be selectively articulated about articulation axis AA-AA by applying axial articulation control motions to the first and second articulation links **3710** and **3690**. In various embodiments, the transmission arrangement **3752** further includes an articulation drive **3770** that is operably supported on the tool mounting plate **3751**. More specifically and with reference to FIG. **90**, it can be seen that a proximal end portion **3772** of an articulation drive shaft **3771** configured to operably engage with the first articulation link **3710** extends through the rotation gear **3755** and is rotatably coupled to a shifter rack gear **3774** that is slidably affixed to the tool mounting plate **3751** through slots **3775**. The articulation drive **3770** further comprises a shifter drive gear **3776** that is coupled to a corresponding third one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **3751** when the tool mounting portion **3750** is coupled to the tool holder **1270**. The articulation drive assembly **3770** further comprises a shifter driven gear **3778** that is rotatably supported on the tool mounting plate **3751** in meshing engagement with the shifter drive gear **3776** and the shifter rack gear **3774**. Application of a third rotary output motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding driven element **1304** will thereby cause rotation of the shifter drive gear **3776** by virtue of being operably coupled thereto. Rotation of the shifter drive gear **3776** ultimately results in the axial movement of the shifter gear rack **3774** and the articulation drive shaft **3771**. The direction of axial travel of the articulation drive shaft **3771** depends upon the direction in which the shifter drive gear **3776** is rotated by the robotic system **1000**. Thus, rotation of the shifter drive gear **3776** in a first rotary direction will result in the axial movement of the articulation drive shaft **3771** in the proximal direction "PD" and cause the cartridge carrier **3630** to pivot in a first direction about articulation axis AA-AA. Conversely, rotation of the shifter drive gear **3776** in a second rotary direction (opposite to the first rotary direction) will result in the axial movement of the articulation drive shaft **3771** in the distal direction "DD" to thereby cause the cartridge carrier **3630** to pivot about articulation axis AA-AA in an opposite direction.

FIG. **91** illustrates yet another surgical tool **3800** embodiment of the present invention that may be employed with a robotic system **1000**. As can be seen in FIG. **91**, the surgical tool **3800** includes a surgical end effector **3812** in the form of an endocutter **3814** that employs various cable-driven components. Various forms of cable driven endocutters are disclosed, for example, in U.S. Pat. No. 7,726,537, entitled "Surgical Stapler With Universal Articulation and Tissue Pre-Clamp" and U.S. Patent Application Publication No. US 2008/0308603A1, entitled "Cable Driven Surgical Stapling and Cutting Instrument With Improved Cable Attachment Arrangements", the disclosures of each are herein incorporated by reference in their respective entireties. Such endocutters **3814** may be referred to as a "disposable loading unit" because they are designed to be disposed of after a single use. However, the various unique and novel arrangements of various embodiments of the present invention may also be employed in connection with cable driven end effectors that are reusable.

As can be seen in FIG. **91**, in at least one form, the endocutter **3814** includes an elongated channel **3822** that operably supports a surgical staple cartridge **3834** therein. An anvil **3824** is pivotally supported for movement relative to the surgical staple cartridge **3834**. The anvil **3824** has a cam surface **3825** that is configured for interaction with a pre-clamping collar **3840** that is supported for axial movement relative thereto. The end effector **3814** is coupled to an elongated shaft assembly **3808** that is attached to a tool mounting portion **3900**. In various embodiments, a closure cable **3850** is employed to move pre-clamping collar **3840** distally onto and over cam surface **3825** to close the anvil **3824** relative to the surgical staple cartridge **3834** and compress the tissue therebetween. Preferably, closure cable **3850** attaches to the pre-clamping collar **3840** at or near point **3841** and is fed through a passageway in anvil **3824** (or under a proximal portion of anvil **3824**) and fed proximally through shaft **3808**. Actuation of closure cable **3850** in the proximal direction "PD" forces pre-clamping collar **3840** distally against cam surface **3825** to close anvil **3824** relative to staple cartridge assembly **3834**. A return mechanism, e.g., a spring, cable system or the like, may be employed to return pre-clamping collar **3840** to a pre-clamping orientation which re-opens the anvil **3824**.

The elongated shaft assembly **3808** may be cylindrical in shape and define a channel **3811** which may be dimensioned to receive a tube adapter **3870**. See FIG. **92**. In various embodiments, the tube adapter **3870** may be slidingly received in friction-fit engagement with the internal channel of elongated shaft **3808**. The outer surface of the tube adapter **3870** may further include at least one mechanical interface, e.g., a cutout or notch **3871**, oriented to mate with a corresponding mechanical interface, e.g., a radially inwardly extending protrusion or detent (not shown), disposed on the inner periphery of internal channel **3811** to lock the tube adapter **3870** to the elongated shaft **3808**. In various embodiments, the distal end of tube adapter **3870** may include a pair of opposing flanges **3872***a* and **3872***b* which define a cavity for pivotably receiving a pivot block **3873** therein. Each flange **3872***a* and **3872***b* may include an aperture **3874***a* and **3874***b* that is oriented to receive a pivot pin **3875** that extends through an aperture in pivot block **3873** to allow pivotable movement of pivot block **3873** about an axis that is perpendicular to longitudinal tool axis "LT-LT". The channel **3822** may be formed with two upwardly extending flanges **3823***a*, **3823***b* that have apertures therein, which are dimensioned to receive a pivot pin **3827**. In turn, pivot pin **3875** mounts through apertures in pivot block **3873** to permit rotation of the surgical end effector **3814** about the "Y" axis as needed during a given surgical procedure. Rotation of pivot block **3873** about pin **3875** along "Z" axis rotates the surgical end effector **3814** about the "Z" axis. See FIG. **92**. Other methods of fastening the elongated channel **3822** to the pivot block **3873** may be effectively employed without departing from the spirit and scope of the present invention.

The surgical staple cartridge **3834** can be assembled and mounted within the elongated channel **3822** during the manufacturing or assembly process and sold as part of the surgical end effector **3812**, or the surgical staple cartridge **3834** may be designed for selective mounting within the elongated channel **3822** as needed and sold separately, e.g., as a single use replacement, replaceable or disposable staple cartridge assembly. It is within the scope of this disclosure that the surgical end effector **3812** may be pivotally, operatively, or integrally attached, for example, to distal end **3809** of the elongated shaft assembly **3808** of a disposable surgical stapler. As is known, a used or spent disposable loading unit **3814** can be removed from the elongated shaft assembly **3808** and replaced with an unused disposable unit. The endocutter **3814** may also preferably include an actuator, preferably a dynamic clamping member **3860**, a sled **3862**, as well as staple pushers (not shown) and staples (not shown) once an unspent or unused cartridge **3834** is mounted in the elongated channel **3822**. See FIG. **92**.

In various embodiments, the dynamic clamping member **3860** is associated with, e.g., mounted on and rides on, or with or is connected to or integral with and/or rides behind sled **3862**. It is envisioned that dynamic clamping member **3860** can have cam wedges or cam surfaces attached or integrally formed or be pushed by a leading distal surface thereof. In various embodiments, dynamic clamping member **3860** may include an upper portion **3863** having a transverse aperture **3864** with a pin **3865** mountable or mounted therein, a central support or upward extension **3866** and substantially T-shaped bottom flange **3867** which cooperate to slidingly retain dynamic clamping member **3860** along an ideal cutting path during longitudinal, distal movement of sled **3862**. The leading cutting edge **3868**, here, knife blade **3869**, is dimensioned to ride within slot **3835** of staple cartridge assembly **3834** and separate tissue once stapled. As used herein, the term "knife assembly" may include the aforementioned dynamic clamping member **3860**, knife **3869**, and sled **3862** or other knife/beam/sled drive arrangements and cutting instrument arrangements. In addition, the various embodiments of the present invention may be employed with knife assembly/cutting instrument arrangements that may be entirely supported in the staple cartridge **3834** or partially supported in the staple cartridge **3834** and elongated channel **3822** or entirely supported within the elongated channel **3822**.

In various embodiments, the dynamic clamping member **3860** may be driven in the proximal and distal directions by a cable drive assembly **3870**. In one non-limiting form, the cable drive assembly comprises a pair of advance cables **3880**, **3882** and a firing cable **3884**. FIGS. **93** and **94** illustrate the cables **3880**, **3882**, **3884** in diagrammatic form. As can be seen in those Figures, a first advance cable **3880** is operably supported on a first distal cable transition support **3885** which may comprise, for example, a pulley, rod, capstan, etc. that is attached to the distal end of the elongated channel **3822** and a first proximal cable transition support **3886** which may comprise, for example, a pulley, rod, capstan, etc. that is operably supported by the elongated channel **3822**. A distal end **3881** of the first advance cable **3880** is affixed to the dynamic clamping assembly **3860**. The second advance cable **3882** is operably supported on a second distal cable transition support **3887** which may, for example, comprise a pulley, rod, capstan etc. that is mounted to the distal end of the elongated channel **3822** and a second proximal cable transition support **3888** which may, for example, comprise a pulley, rod, capstan, etc. mounted to the proximal end of the elongated channel **3822**. The proximal end **3883** of the second advance cable **3882** may be attached to the dynamic clamping assembly **3860**. Also in these embodiments, an endless firing cable **3884** is employed and journaled on a support **3889** that may comprise a pulley, rod, capstan, etc. mounted within the elongated shaft **3808**. In one embodiment, the retract cable **3884** may be formed in a loop and coupled to a connector **3889'** that is fixedly attached to the first and second advance cables **3880**, **3882**.

Various non-limiting embodiments of the present invention include a cable drive transmission **3920** that is operably supported on a tool mounting plate **3902** of the tool mounting portion **3900**. The tool mounting portion **3900** has an array of electrical connecting pins **3904** which are configured to interface with the slots **1258** (FIG. **33**) in the adapter **1240'**. Such arrangement permits the robotic system **1000** to provide control signals to a control circuit **3910** of the tool **3800**. While the interface is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

Control circuit **3910** is shown in schematic form in FIG. **91**. In one form or embodiment, the control circuit **3910** includes a power supply in the form of a battery **3912** that is coupled to an on-off solenoid powered switch **3914**. In other embodiments, however, the power supply may comprise a source of alternating current. Control circuit **3910** further includes an on/off solenoid **3916** that is coupled to a double pole switch **3918** for controlling motor rotation direction. Thus, when the robotic system **1000** supplies an appropriate control signal, switch **3914** will permit battery **3912** to supply power to the double pole switch **3918**. The robotic system **1000** will also supply an appropriate signal to the double pole switch **3918** to supply power to a shifter motor **3922**.

Turning to FIGS. **95-100**, at least one embodiment of the cable drive transmission **3920** comprises a drive pulley **3930** that is operably mounted to a drive shaft **3932** that is attached to a driven element **1304** of the type and construction described above that is designed to interface with a corresponding drive element **1250** of the adapter **1240**. See FIGS. **33** and **98**. Thus, when the tool mounting portion **3900** is operably coupled to the tool holder **1270**, the robot system **1000** can apply rotary motion to the drive pulley **3930** in a desired direction. A first drive member or belt **3934** drivingly engages the drive pulley **3930** and a second drive shaft **3936** that is rotatably supported on a shifter yoke **3940**. The shifter yoke **3940** is operably coupled to the shifter motor **3922** such that rotation of the shaft **3923** of the shifter motor **3922** in a first direction will shift the shifter yoke in a first direction "FD" and rotation of the shifter motor shaft **3923** in a second direction will shift the shifter yoke **3940** in a second direction "SD". Other embodiments of the present invention may employ a shifter solenoid arrangement for shifting the shifter yoke in said first and second directions.

As can be seen in FIGS. **95-98**, a closure drive gear **3950** mounted to a second drive shaft **3936** and is configured to selectively mesh with a closure drive assembly, generally designated as **3951**. Likewise a firing drive gear **3960** is also mounted to the second drive shaft **3936** and is configured to selectively mesh with a firing drive assembly generally designated as **3961**. Rotation of the second drive shaft **3936** causes the closure drive gear **3950** and the firing drive gear **3960** to rotate. In one non-limiting embodiment, the closure drive assembly **3951** comprises a closure driven gear **3952** that is coupled to a first closure pulley **3954** that is rotatably supported on a third drive shaft **3956**. The closure cable **3850** is drivingly received on the first closure pulley **3954** such that rotation of the closure driven gear **3952** will drive the closure cable **3850**. Likewise, the firing drive assembly **3961** comprises a firing driven gear **3962** that is coupled to a first firing pulley **3964** that is rotatably supported on the third drive shaft **3956**. The first and second driving pulleys **3954** and **3964** are independently rotatable on the third drive shaft **3956**. The firing cable **3884** is drivingly received on the first firing pulley **3964** such that rotation of the firing driven gear **3962** will drive the firing cable **3884**.

Also in various embodiments, the cable drive transmission **3920** further includes a braking assembly **3970**. In at least one embodiment, for example, the braking assembly **3970** includes a closure brake **3972** that comprises a spring arm **3973** that is attached to a portion of the transmission housing **3971**. The closure brake **3972** has a gear lug **3974** that is sized to engage the teeth of the closure driven gear **3952** as will be discussed in further detail below. The braking assembly **3970** further includes a firing brake **3976** that comprises a spring arm **3977** that is attached to another portion of the transmission housing **3971**. The firing brake **3976** has a gear lug **3978** that is sized to engage the teeth of the firing driven gear **3962**.

At least one embodiment of the surgical tool **3800** may be used as follows. The tool mounting portion **3900** is operably coupled to the interface **1240** of the robotic system **1000**. The controller or control unit of the robotic system is operated to locate the tissue to be cut and stapled between the open anvil **3824** and the staple cartridge **3834**. When in that initial position, the braking assembly **3970** has locked the closure driven gear **3952** and the firing driven gear **3962** such that they cannot rotate. That is, as shown in FIG. **96**, the gear lug **3974** is in locking engagement with the closure driven gear **3952** and the gear lug **3978** is in locking engagement with the firing driven gear **3962**. Once the surgical end effector **3814** has been properly located, the controller **1001** of the robotic system **1000** will provide a control signal to the shifter motor **3922** (or shifter solenoid) to move the shifter yoke **3940** in the first direction. As the shifter yoke **3940** is moved in the first direction, the closure drive gear **3950** moves the gear lug **3974** out of engagement with the closure driven gear **3952** as it moves into meshing engagement with the closure driven gear **3952**. As can be seen in FIG. **95**, when in that position, the gear lug **3978** remains in locking engagement with the firing driven gear **3962** to prevent actuation of the firing system. Thereafter, the robotic controller **1001** provides a first rotary actuation motion to the drive pulley **3930** through the interface between the driven element **1304** and the corresponding components of the tool holder **1240**. As the drive pulley **3930** is rotated in the first direction, the closure cable **3850** is rotated to drive the preclamping collar **3840** into closing engagement with the cam surface **3825** of the anvil **3824** to move it to the closed position thereby clamping the target tissue between the anvil **3824** and the staple cartridge **3834**. See FIG. **91**. Once the anvil **3824** has been moved to the closed position, the robotic controller **1001** stops the application of the first rotary motion to the drive pulley **3930**. Thereafter, the robotic controller **1001** may commence the firing process by sending another control signal to the shifter motor **3922** (or shifter solenoid) to cause the shifter yoke to move in the second direction "SD" as shown in FIG. **97**. As the shifter yoke **3940** is moved in the second direction, the firing drive gear **3960** moves the gear lug **3978** out of engagement with the firing driven gear **3962** as it moves into meshing engagement with the firing driven gear **3962**. As can be seen in FIG. **97**, when in that position, the gear lug **3974** remains in locking engagement with the closure driven gear **3952** to prevent actuation of the closure system. Thereafter, the robotic controller **1001** is activated to provide the first rotary actuation motion to the drive pulley **3930** through the interface between the driven element **1304** and the corresponding components of the tool holder **1240**. As the drive pulley **3930** is rotated in the first direction, the firing cable **3884** is rotated to drive the dynamic clamping member **3860** in the distal direction "DD" thereby firing the stapes and cutting the tissue clamped in the end effector **3814**. Once the robotic system **1000** determines that the dynamic clamping member **3860** has reached its distal most position—either through sensors or through monitoring the amount of rotary input applied to the drive pulley **3930**, the controller **1001** may then apply a second rotary motion to the drive pulley **3930** to rotate the closure cable **3850** in an opposite direction to cause the dynamic clamping member **3860** to be retracted in the proximal direction "PD". Once the dynamic clamping member has been retracted to the starting position, the application of the second rotary motion to the drive pulley **3930** is discontinued. Thereafter, the shifter motor **3922** (or shifter solenoid) is powered to move the shifter yoke **3940** to the closure position (FIG. **95**). Once the closure drive gear **3950** is in meshing engagement with the closure driven gear **3952**, the robotic controller **1001** may once again apply the second rotary motion to the drive pulley **3930**. Rotation of the drive pulley **3930** in the second direction causes the closure cable **3850** to retract the preclamping collar **3840** out of engagement with the cam surface **3825** of the anvil **3824** to permit the anvil **3824** to move to an open position (by a spring or other means) to release the stapled tissue from the surgical end effector **3814**.

FIG. **101** illustrates a surgical tool **4000** that employs a gear driven firing bar **4092** as shown in FIGS. **102-104**. This embodiment includes an elongated shaft assembly **4008** that extends from a tool mounting portion **4100**. The tool mounting portion **4100** includes a tool mounting plate **4102** that operable supports a transmission arrangement **4103** thereon. The elongated shaft assembly **4008** includes a rotatable proximal closure tube **4010** that is rotatably journaled on a proximal spine member **4020** that is rigidly coupled to the tool mounting plate **4102**. The proximal spine member **4020** has a distal end that is coupled to an elongated channel portion **4022** of a surgical end effector **4012**. The surgical effector **4012** may be substantially similar to surgical end effector **3412** described above. In addition, the anvil **4024** of the surgical end effector **4012** may be opened and closed by a distal closure tube **4030** that operably interfaces with the proximal closure tube **4010**. Distal closure tube **4030** is identical to distal closure tube **3430** described above. Similarly, proximal closure tube **4010** is identical to proximal closure tube segment **3410** described above.

Anvil **4024** is opened and closed by rotating the proximal closure tube **4010** in manner described above with respect to distal closure tube **3410**. In at least one embodiment, the transmission arrangement comprises a closure transmission, generally designated as **4011**. As will be further discussed below, the closure transmission **4011** is configured to receive a corresponding first rotary motion from the robotic system **1000** and convert that first rotary motion to a primary rotary motion for rotating the rotatable proximal closure tube **4010** about the longitudinal tool axis LT-LT. As can be seen in FIG. **104**, a proximal end **4060** of the proximal closure tube **4010** is rotatably supported within a cradle arrangement **4104** that is attached to a tool mounting plate **4102** of the tool mounting portion **4100**. A rotation gear **4062** is formed on or attached to the proximal end **4060** of the closure tube segment **4010** for meshing engagement with a rotation drive assembly **4070** that is operably supported on the tool mounting plate **4102**. In at least one embodiment, a rotation drive gear **4072** is coupled to a corresponding first one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **4102** when the tool mounting portion **4100** is coupled to the tool holder **1270**. See FIGS. **34** and **104**. The rotation drive assembly **4070** further comprises a rotary driven gear **4074** that is rotatably supported on the tool mounting plate **4102** in meshing engagement with the rotation gear **4062** and the rotation drive gear **4072**. Application of a first rotary control motion from the robotic system **1000** through the tool holder **1270** and the adapter **1240** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **4072** by virtue of being operably coupled thereto. Rotation of the rotation drive gear **4072** ultimately results in the rotation of the closure tube segment **4010** to open and close the anvil **4024** as described above.

As indicated above, the end effector **4012** employs a cutting element **3860** as shown in FIGS. **102** and **103**. In at least one non-limiting embodiment, the transmission arrangement **4103** further comprises a knife drive transmission that includes a knife drive assembly **4080**. FIG. **104** illustrates one form of knife drive assembly **4080** for axially advancing the knife bar **4092** that is attached to such cutting element using cables as described above with respect to surgical tool **3800**. In particular, the knife bar **4092** replaces the firing cable **3884** employed in an embodiment of surgical tool **3800**. One form of the knife drive assembly **4080** comprises a rotary drive gear **4082** that is coupled to a corresponding second one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **4102** when the tool mounting portion **4100** is coupled to the tool holder **1270**. See FIGS. **34** and **104**. The knife drive assembly **4080** further comprises a first rotary driven gear assembly **4084** that is rotatably supported on the tool mounting plate **4102**. The first rotary driven gear assembly **4084** is in meshing engagement with a third rotary driven gear assembly **4086** that is rotatably supported on the tool mounting plate **4102** and which is in meshing engagement with a fourth rotary driven gear assembly **4088** that is in meshing engagement with a threaded portion **4094** of drive shaft assembly **4090** that is coupled to the knife bar **4092**. Rotation of the rotary drive gear **4082** in a second rotary direction will result in the axial advancement of the drive shaft assembly **4090** and knife bar **4092** in the distal direction "DD". Conversely, rotation of the rotary drive gear **4082** in a secondary rotary direction (opposite to the second rotary direction) will cause the drive shaft assembly **4090** and the knife bar **4092** to move in the proximal direction. Movement of the firing bar **4092** in the proximal direction "PD" will drive the cutting element **3860** in the distal direction "DD". Conversely, movement of the firing bar **4092** in the distal direction "DD" will result in the movement of the cutting element **3860** in the proximal direction "PD".

FIGS. **105-111** illustrate yet another surgical tool **5000** that may be effectively employed in connection with a robotic system **1000**. In various forms, the surgical tool **5000** includes a surgical end effector **5012** in the form of a surgical stapling instrument that includes an elongated channel **5020** and a pivotally translatable clamping member, such as an anvil **5070**, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector **5012**. As can be seen in FIG. **107**, the elongated channel **5020** may be substantially U-shaped in cross-section and be fabricated from, for example, titanium, 203 stainless steel, 304 stainless steel, 416 stainless steel, 17-4 stainless steel, 17-7 stainless steel, 6061 or 7075 aluminum, chromium steel, ceramic, etc. A substantially U-shaped metal channel pan **5022** may be supported in the bottom of the elongated channel **5020** as shown.

Various embodiments include an actuation member in the form of a sled assembly **5030** that is operably supported within the surgical end effector **5012** and axially movable therein between a staring position and an ending position in response to control motions applied thereto. In some forms, the metal channel pan **5022** has a centrally-disposed slot **5024** therein to movably accommodate a base portion **5032** of the sled assembly **5030**. The base portion **5032** includes a foot portion **5034** that is sized to be slidably received in a slot **5021** in the elongated channel **5020**. See FIG. **107**. As can be seen in FIGS. **107**, **110**, and **111**, the base portion **5032** of sled assembly **5030** includes an axially extending threaded bore **5036** that is configured to be threadedly received on a threaded drive shaft **5130** as will be discussed in further detail below. In addition, the sled assembly **5030** includes an upstanding support portion **5038** that supports a tissue cutting blade or tissue cutting instrument **5040**. The upstanding support portion **5038** terminates in a top portion **5042** that has a pair of laterally extending retaining fins **5044** protruding therefrom. As shown in FIG. **107**, the fins **5044** are positioned to be received within corresponding slots **5072** in anvil **5070**. The fins **5044** and the foot **5034** serve to retain the anvil **5070** in a desired spaced closed position as the sled assembly **5030** is driven distally through the tissue clamped within the surgical end effector **5014**. As can also be seen in FIGS. **109** and **111**, the sled assembly **5030** further includes a reciprocatably or sequentially activatable drive assembly **5050** for driving staple pushers toward the closed anvil **5070**.

More specifically and with reference to FIGS. **107** and **108**, the elongated channel **5020** is configured to operably support a surgical staple cartridge **5080** therein. In at least one form, the surgical staple cartridge **5080** comprises a body portion **5082** that may be fabricated from, for example, Vectra, Nylon (6/6 or 6/12) and include a centrally disposed slot **5084** for accommodating the upstanding support portion **5038** of the sled assembly **5030**. See FIG. **107**. These materials could also be filled with glass, carbon, or mineral fill of 10%-40%. The surgical staple cartridge **5080** further includes a plurality of cavities **5086** for movably supporting lines or rows of staple-supporting pushers **5088** therein. The cavities **5086** may be arranged in spaced longitudinally extending lines or rows **5090**, **5092**, **5094**, **5096**. For example, the rows **5090** may be referred to herein as first outboard rows. The rows **5092** may be referred to herein as first inboard rows. The rows **5094** may be referred to as second inboard rows and the rows **5096** may be referred to as second outboard rows. The first inboard row **5090** and the first outboard row **5092** are located on a first lateral side of the longitudinal slot **5084** and the second inboard row **5094** and the second outboard row **5096** are located on a second lateral side of the longitudinal slot **5084**. The first staple pushers **5088** in the first inboard row **5092** are staggered in relationship to the first staple pushers **5088** in the first outboard row **5090**. Similarly, the second staple pushers **5088** in the second outboard row **5096** are staggered in relationship to the second pushers **5088** in the second inboard row **5094**. Each pusher **5088** operably supports a surgical staple **5098** thereon.

In various embodiments, the sequentially-activatable or reciprocatably-activatable drive assembly **5050** includes a pair of outboard drivers **5052** and a pair of inboard drivers **5054** that are each attached to a common shaft **5056** that is rotatably mounted within the base **5032** of the sled assembly **5030**. The outboard drivers **5052** are oriented to sequentially or reciprocatingly engage a corresponding plurality of outboard activation cavities **5026** provided in the channel pan **5022**. Likewise, the inboard drivers **5054** are oriented to sequentially or reciprocatingly engage a corresponding plurality of inboard activation cavities **5028** provided in the channel pan **5022**. The inboard activation cavities **5028** are arranged in a staggered relationship relative to the adjacent outboard activation cavities **5026**. See FIG. **108**. As can also be seen in FIGS. **108** and **110**, in at least one embodiment, the sled assembly **5030** further includes distal wedge segments **5060** and intermediate wedge segments **5062** located on each side of the bore **5036** to engage the pushers **5088** as the sled assembly **5030** is driven distally in the distal direction "DD". As indicated above, the sled assembly **5030** is threadedly received on a threaded portion **5132** of a drive shaft **5130** that is rotatably supported within the end effector **5012**. In various embodiments, for example, the drive shaft **5130** has a distal end **5134** that is supported in a distal bearing **5136** mounted in the surgical end effector **5012**. See FIGS. **107** and **108**.

In various embodiments, the surgical end effector **5012** is coupled to a tool mounting portion **5200** by an elongated shaft assembly **5108**. In at least one embodiment, the tool mounting portion **5200** operably supports a transmission arrangement generally designated as **5204** that is configured to receive rotary output motions from the robotic system. The elongated shaft assembly **5108** includes an outer closure tube **5110** that is rotatable and axially movable on a spine member **5120** that is rigidly coupled to a tool mounting plate **5201** of the tool mounting portion **5200**. The spine member **5120** also has a distal end **5122** that is coupled to the elongated channel portion **5020** of the surgical end effector **5012**.

In use, it may be desirable to rotate the surgical end effector **5012** about a longitudinal tool axis LT-LT defined by the elongated shaft assembly **5008**. In various embodiments, the outer closure tube **5110** has a proximal end **5112** that is rotatably supported on the tool mounting plate **5201** of the tool drive portion **5200** by a forward support cradle **5203**. The proximal end **5112** of the outer closure tube **5110** is configured to operably interface with a rotation transmission portion **5206** of the transmission arrangement **5204**. In various embodiments, the proximal end **5112** of the outer closure tube **5110** is also supported on a closure sled **5140** that is also movably supported on the tool mounting plate **5201**. A closure tube gear segment **5114** is formed on the proximal end **5112** of the outer closure tube **5110** for meshing engagement with a rotation drive assembly **5150** of the rotation transmission **5206**. As can be seen in FIG. **105**, the rotation drive assembly **5150**, in at least one embodiment, comprises a rotation drive gear **5152** that is coupled to a corresponding first one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **5201** when the tool drive portion **5200** is coupled to the tool holder **1270**. The rotation drive assembly **5150** further comprises a rotary driven gear **5154** that is rotatably supported on the tool mounting plate **5201** in meshing engagement with the closure tube gear segment **5114** and the rotation drive gear **5152**. Application of a first rotary control motion from the robotic system **1000** through the tool holder **1270** and the adapter **1240** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **5152**. Rotation of the rotation drive gear **5152** ultimately results in the rotation of the elongated shaft assembly **5108** (and the end effector **5012**) about the longitudinal tool axis LT-LT (represented by arrow "R" in FIG. **105**).

Closure of the anvil **5070** relative to the surgical staple cartridge **5080** is accomplished by axially moving the outer closure tube **5110** in the distal direction "DD". Such axial movement of the outer closure tube **5110** may be accomplished by a closure transmission portion closure transmission portion **5144** of the transmission arrangement **5204**. As indicated above, in various embodiments, the proximal end **5112** of the outer closure tube **5110** is supported by the closure sled **5140** which enables the proximal end **5112** to rotate relative thereto, yet travel axially with the closure sled **5140**. In particular, as can be seen in FIG. **105**, the closure sled **5140** has an upstanding tab **5141** that extends into a radial groove **5115** in the proximal end portion **5112** of the outer closure tube **5110**. In addition, as was described above, the closure sled **5140** is slidably mounted to the tool mounting plate **5201**. In various embodiments, the closure sled **5140** has an upstanding portion **5142** that has a closure rack gear **5143** formed thereon. The closure rack gear **5143** is configured for driving engagement with the closure transmission **5144**.

In various forms, the closure transmission **5144** includes a closure spur gear **5145** that is coupled to a corresponding second one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **5201**. Thus, application of a second rotary control motion from the robotic system **1000** through the tool holder **1270** and the adapter **1240** to the corresponding second driven element **1304** will cause rotation of the closure spur gear **5145** when the interface **1230** is coupled to the tool mounting portion **5200**. The closure transmission **5144** further includes a driven closure gear set **5146** that is supported in meshing engagement with the closure spur gear **5145** and the closure rack gear **5143**. Thus, application of a second rotary control motion from the robotic system **1000** through the tool holder **1270** and the adapter **1240** to the corresponding second driven element **1304** will cause rotation of the closure spur gear **5145** and ultimately drive the closure sled **5140** and the outer closure tube **5110** axially. The axial direction in which the closure tube **5110** moves ultimately depends upon the direction in which the second driven element **1304** is rotated. For example, in response to one rotary closure motion received from the robotic system **1000**, the closure sled **5140** will be driven in the distal direction “DD” and ultimately the outer closure tube **5110** will be driven in the distal direction as well. The outer closure tube **5110** has an opening **5117** in the distal end **5116** that is configured for engagement with a tab **5071** on the anvil **5070** in the manners described above. As the outer closure tube **5110** is driven distally, the proximal end **5116** of the closure tube **5110** will contact the anvil **5070** and pivot it closed. Upon application of an “opening” rotary motion from the robotic system **1000**, the closure sled **5140** and outer closure tube **5110** will be driven in the proximal direction “PD” and pivot the anvil **5070** to the open position in the manners described above.

In at least one embodiment, the drive shaft **5130** has a proximal end **5137** that has a proximal shaft gear **5138** attached thereto. The proximal shaft gear **5138** is supported in meshing engagement with a distal drive gear **5162** attached to a rotary drive bar **5160** that is rotatably supported with spine member **5120**. Rotation of the rotary drive bar **5160** and ultimately rotary drive shaft **5130** is controlled by a rotary knife transmission **5207** which comprises a portion of the transmission arrangement **5204** supported on the tool mounting plate **5210**. In various embodiments, the rotary knife transmission **5207** comprises a rotary knife drive system **5170** that is operably supported on the tool mounting plate **5201**. In various embodiments, the knife drive system **5170** includes a rotary drive gear **5172** that is coupled to a corresponding third one of the driven discs or elements **1304** on the adapter side of the tool mounting plate **5201** when the tool drive portion **5200** is coupled to the tool holder **1270**. The knife drive system **5170** further comprises a first rotary driven gear **5174** that is rotatably supported on the tool mounting plate **5201** in meshing engagement with a second rotary driven gear **5176** and the rotary drive gear **5172**. The second rotary driven gear **5176** is coupled to a proximal end portion **5164** of the rotary drive bar **5160**.

Rotation of the rotary drive gear **5172** in a first rotary direction will result in the rotation of the rotary drive bar **5160** and rotary drive shaft **5130** in a first direction. Conversely, rotation of the rotary drive gear **5172** in a second rotary direction (opposite to the first rotary direction) will cause the rotary drive bar **5160** and rotary drive shaft **5130** to rotate in a second direction. **2400**. Thus, rotation of the drive shaft **2440** results in rotation of the drive sleeve **2400**.

One method of operating the surgical tool **5000** will now be described. The tool drive **5200** is operably coupled to the interface **1240** of the robotic system **1000**. The controller **1001** of the robotic system **1000** is operated to locate the tissue to be cut and stapled between the open anvil **5070** and the surgical staple cartridge **5080**. Once the surgical end effector **5012** has been positioned by the robot system **1000** such that the target tissue is located between the anvil **5070** and the surgical staple cartridge **5080**, the controller **1001** of the robotic system **1000** may be activated to apply the second rotary output motion to the second driven element **1304** coupled to the closure spur gear **5145** to drive the closure sled **5140** and the outer closure tube **5110** axially in the distal direction to pivot the anvil **5070** closed in the manner described above. Once the robotic controller **1001** determines that the anvil **5070** has been closed by, for example, sensors in the surgical end effector **5012** and/or the tool drive portion **5200**, the robotic controller **1001** system may provide the surgeon with an indication that signifies the closure of the anvil. Such indication may be, for example, in the form of a light and/or audible sound, tactile feedback on the control members, etc. Then the surgeon may initiate the firing process. In alternative embodiments, however, the robotic controller **1001** may automatically commence the firing process.

To commence the firing process, the robotic controller applies a third rotary output motion to the third driven disc or element **1304** coupled to the rotary drive gear **5172**. Rotation of the rotary drive gear **5172** results in the rotation of the rotary drive bar **5160** and rotary drive shaft **5130** in the manner described above. Firing and formation of the surgical staples **5098** can be best understood from reference to FIGS. **106**, **108**, and **109**. As the sled assembly **5030** is driven in the distal direction “DD” through the surgical staple cartridge **5080**, the distal wedge segments **5060** first contact the staple pushers **5088** and start to move them toward the closed anvil **5070**. As the sled assembly **5030** continues to move distally, the outboard drivers **5052** will drop into the corresponding activation cavity **5026** in the channel pan **5022**. The opposite end of each outboard driver **5052** will then contact the corresponding outboard pusher **5088** that has moved up the distal and intermediate wedge segments **5060**, **5062**. Further distal movement of the sled assembly **5030** causes the outboard drivers **5052** to rotate and drive the corresponding pushers **5088** toward the anvil **5070** to cause the staples **5098** supported thereon to be formed as they are driven into the anvil **5070**. It will be understood that as the sled assembly **5030** moves distally, the knife blade **5040** cuts through the tissue that is clamped between the anvil and the staple cartridge. Because the inboard drivers **5054** and outboard drivers **5052** are attached to the same shaft **5056** and the inboard drivers **5054** are radially offset from the outboard drivers **5052** on the shaft **5056**, as the outboard drivers **5052** are driving their corresponding pushers **5088** toward the anvil **5070**, the inboard drivers **5054** drop into their next corresponding activation cavity **5028** to cause them to rotatably or reciprocatingly drive the corresponding inboard pushers **5088** towards the closed anvil **5070** in the same manner. Thus, the laterally corresponding outboard staples **5098** on each side of the centrally disposed slot **5084** are simultaneously formed together and the laterally corresponding inboard staples **5098** on each side of the slot **5084** are simultaneously formed together as the sled assembly **5030** is driven distally. Once the robotic controller **1001** determines that the sled assembly **5030** has reached its distal most position—either through sensors or through monitoring the amount of rotary input applied to the drive shaft **5130** and/or the rotary drive bar **5160**, the controller **1001** may then apply a third rotary output motion to the drive shaft **5130** to rotate the drive shaft **5130** in an opposite direction to retract the sled assembly **5030** back to its starting position. Once the sled assembly **5030** has been retracted to the starting position (as signaled by sensors in the end effector **5012** and/or the tool drive portion **5200**), the application of the second rotary motion to the drive shaft **5130** is discontinued. Thereafter, the surgeon may manually activate the anvil opening process or it may be automatically commenced by the robotic controller **1001**. To open the anvil **5070**, the second rotary output motion is applied to the closure spur gear **5145** to drive the closure sled **5140** and the outer closure tube **5110** axially in the proximal direction. As the closure tube **5110** moves proximally, the opening **5117** in the distal end **5116** of the closure tube **5110** contacts the tab **5071** on the anvil **5070** to pivot the anvil **5070** to the open position. A spring may also be employed to bias the anvil **5070** to the open position when the closure tube **5116** has been returned to the starting position. Again, sensors in the surgical end effector **5012** and/or the tool mounting portion **5200** may provide the robotic controller **1001** with a signal indicating that the anvil **5070** is now open. Thereafter, the surgical end effector **5012** may be withdrawn from the surgical site.

FIGS. **112-117** diagrammatically depict the sequential firing of staples in a surgical tool assembly **5000'** that is substantially similar to the surgical tool assembly **5000** described above. In this embodiment, the inboard and outboard drivers **5052'**, **5054'** have a cam-like shape with a cam surface **5053** and an actuator protrusion **5055** as shown in FIGS. **112-118**. The drivers **5052'**, **5054'** are journaled on the same shaft **5056'** that is rotatably supported by the sled assembly **5030'**. In this embodiment, the sled assembly **5030'** has distal wedge segments **5060'** for engaging the pushers **5088**. FIG. **112** illustrates an initial position of two inboard or outboard drivers **5052'**, **5054'** as the sled assembly **5030'** is driven in the distal direction "DD". As can be seen in that Figure, the pusher **5088***a* has advanced up the wedge segment **5060'** and has contacted the driver **5052'**, **5054'**. Further travel of the sled assembly **5030'** in the distal direction causes the driver **5052'**, **5054'** to pivot in the "P" direction (FIG. **113**) until the actuator portion **5055** contacts the end wall **5029***a* of the activation cavity **5026**, **5028** as shown in FIG. **114**. Continued advancement of the sled assembly **5030'** in the distal direction "DD" causes the driver **5052'**, **5054'** to rotate in the "D" direction as shown in FIG. **115**. As the driver **5052'**, **5054'** rotates, the pusher **5088***a* rides up the cam surface **5053** to the final vertical position shown in FIG. **116**. When the pusher **5088***a* reaches the final vertical position shown in FIGS. **116** and **117**, the staple (not shown) supported thereon has been driven into the staple forming surface of the anvil to form the staple.

FIGS. **119-124** illustrate a surgical end effector **5312** that may be employed for example, in connection with the tool mounting portion **1300** and shaft **2008** described in detail above. In various forms, the surgical end effector **5312** includes an elongated channel **5322** that is constructed as described above for supporting a surgical staple cartridge **5330** therein. The surgical staple cartridge **5330** comprises a body portion **5332** that includes a centrally disposed slot **5334** for accommodating an upstanding support portion **5386** of a sled assembly **5380**. See FIGS. **119-121**. The surgical staple cartridge body portion **5332** further includes a plurality of cavities **5336** for movably supporting staple-supporting pushers **5350** therein. The cavities **5336** may be arranged in spaced longitudinally extending rows **5340**, **5342**, **5344**, **5346**. The rows **5340**, **5342** are located on one lateral side of the longitudinal slot **5334** and the rows **5344**, **5346** are located on the other side of longitudinal slot **5334**. In at least one embodiment, the pushers **5350** are configured to support two surgical staples **5352** thereon. In particular, each pusher **5350** located on one side of the elongated slot **5334** supports one staple **5352** in row **5340** and one staple **5352** in row **5342** in a staggered orientation. Likewise, each pusher **5350** located on the other side of the elongated slot **5334** supports one surgical staple **5352** in row **5344** and another surgical staple **5352** in row **5346** in a staggered orientation. Thus, every pusher **5350** supports two surgical staples **5352**.

As can be further seen in FIGS. **119**, **120**, the surgical staple cartridge **5330** includes a plurality of rotary drivers **5360**. More particularly, the rotary drivers **5360** on one side of the elongated slot **5334** are arranged in a single line **5370** and correspond to the pushers **5350** in lines **5340**, **5342**. In addition, the rotary drivers **5360** on the other side of the elongated slot **5334** are arranged in a single line **5372** and correspond to the pushers **5350** in lines **5344**, **5346**. As can be seen in FIG. **119**, each rotary driver **5360** is rotatably supported within the staple cartridge body **5332**. More particularly, each rotary driver **5360** is rotatably received on a corresponding driver shaft **5362**. Each driver **5360** has an arcuate ramp portion **5364** formed thereon that is configured to engage an arcuate lower surface **5354** formed on each pusher **5350**. See FIG. **124**. In addition, each driver **5360** has a lower support portion **5366** extend therefrom to slidably support the pusher **5360** on the channel **5322**. Each driver **5360** has a downwardly extending actuation rod **5368** that is configured for engagement with a sled assembly **5380**.

As can be seen in FIG. **121**, in at least one embodiment, the sled assembly **5380** includes a base portion **5382** that has a foot portion **5384** that is sized to be slidably received in a slot **5333** in the channel **5322**. See FIG. **119**. The sled assembly **5380** includes an upstanding support portion **5386** that supports a tissue cutting blade or tissue cutting instrument **5388**. The upstanding support portion **5386** terminates in a top portion **5390** that has a pair of laterally extending retaining fins **5392** protruding therefrom. The fins **5392** are positioned to be received within corresponding slots (not shown) in the anvil (not shown). As with the above-described embodiments, the fins **5392** and the foot portion **5384** serve to retain the anvil (not shown) in a desired spaced closed position as the sled assembly **5380** is driven distally through the tissue clamped within the surgical end effector **5312**. The upstanding support portion **5386** is configured for attachment to a knife bar **2200** (FIG. **40**). The sled assembly **5380** further has a horizontally-extending actuator plate **5394** that is shaped for actuating engagement with each of the actuation rods **5368** on the pushers **5360**.

Operation of the surgical end effector **5312** will now be explained with reference to FIGS. **119** and **120**. As the sled assembly **5380** is driven in the distal direction "DD" through the staple cartridge **5330**, the actuator plate **5394** sequentially contacts the actuation rods **5368** on the pushers **5360**. As the sled assembly **5380** continues to move distally, the actuator plate **5394** sequentially contacts the actuator rods **5368** of the drivers **5360** on each side of the elongated slot **5334**. Such action causes the drivers **5360** to rotate from a first unactuated position to an actuated portion wherein the pushers **5350** are driven towards the closed anvil. As the pushers **5350** are driven toward the anvil, the surgical staples **5352** thereon are driven into forming contact with the underside of the anvil. Once the robotic system **1000** determines that the sled assembly **5080** has reached its distal most position through sensors or other means, the control system of the robotic system **1000** may then retract the knife bar and sled assembly **5380** back to the starting position. Thereafter, the robotic control system may then activate the procedure for returning the anvil to the open position to release the stapled tissue.

FIGS. **125-129** depict one form of an automated reloading system embodiment of the present invention, generally designated as **5500**. In one form, the automated reloading system **5500** is configured to replace a "spent" surgical end effector component in a manipulatable surgical tool portion of a robotic surgical system with a "new" surgical end effector component. As used herein, the term "surgical end effector component" may comprise, for example, a surgical staple cartridge, a disposable loading unit or other end effector components that, when used, are spent and must be replaced with a new component. Furthermore, the term "spent" means that the end effector component has been activated and is no longer useable for its intended purpose in its present state. For example, in the context of a surgical staple cartridge or disposable loading unit, the term "spent" means that at least some of the unformed staples that were previously supported therein have been "fired" therefrom. As used herein, the term "new" surgical end effector component refers to an end effector component that is in condition for its intended use. In the context of a surgical staple cartridge or disposable loading unit, for example, the term "new" refers to such a component that has unformed staples therein and which is otherwise ready for use.

In various embodiments, the automated reloading system **5500** includes a base portion **5502** that may be strategically located within a work envelope **1109** of a robotic arm cart **1100** (FIG. **26**) of a robotic system **1000**. As used herein, the term "manipulatable surgical tool portion" collectively refers to a surgical tool of the various types disclosed herein and other forms of surgical robotically-actuated tools that are operably attached to, for example, a robotic arm cart **1100** or similar device that is configured to automatically manipulate and actuate the surgical tool. The term "work envelope" as used herein refers to the range of movement of the manipulatable surgical tool portion of the robotic system. FIG. **26** generally depicts an area that may comprise a work envelope of the robotic arm cart **1100**. Those of ordinary skill in the art will understand that the shape and size of the work envelope depicted therein is merely illustrative. The ultimate size, shape and location of a work envelope will ultimately depend upon the construction, range of travel limitations, and location of the manipulatable surgical tool portion. Thus, the term "work envelope" as used herein is intended to cover a variety of different sizes and shapes of work envelopes and should not be limited to the specific size and shape of the sample work envelope depicted in FIG. **26**.

As can be seen in FIG. **125**, the base portion **5502** includes a new component support section or arrangement **5510** that is configured to operably support at least one new surgical end effector component in a "loading orientation". As used herein, the term "loading orientation" means that the new end effector component is supported in such away so as to permit the corresponding component support portion of the manipulatable surgical tool portion to be brought into loading engagement with (i.e., operably seated or operably attached to) the new end effector component (or the new end effector component to be brought into loading engagement with the corresponding component support portion of the manipulatable surgical tool portion) without human intervention beyond that which may be necessary to actuate the robotic system. As will be further appreciated as the present Detailed Description proceeds, in at least one embodiment, the preparation nurse will load the new component support section before the surgery with the appropriate length and color cartridges (some surgical staple cartridges may support certain sizes of staples the size of which may be indicated by the color of the cartridge body) required for completing the surgical procedure. However, no direct human interaction is necessary during the surgery to reload the robotic endocutter. In one form, the surgical end effector component comprises a staple cartridge **2034** that is configured to be operably seated within a component support portion (elongated channel) of any of the various other end effector arrangements described above. For explanation purposes, new (unused) cartridges will be designated as "**2034***a*" and spent cartridges will be designated as "**2034***b*". The Figures depict cartridges **2034***a*, **2034***b* designed for use with a surgical end effector **2012** that includes a channel **2022** and an anvil **2024**, the construction and operation of which were discussed in detail above. Cartridges **2034***a*, **2034***b* are identical to cartridges **2034** described above. In various embodiments, the cartridges **2034***a*, **2034***b* are configured to be snappingly retained (i.e., loading engagement) within the channel **2022** of a surgical end effector **2012**. As the present Detailed Description proceeds, however, those of ordinary skill in the art will appreciate that the unique and novel features of the automated cartridge reloading system **5500** may be effectively employed in connection with the automated removal and installation of other cartridge arrangements without departing from the spirit and scope of the present invention.

In the depicted embodiment, the term "loading orientation" means that the distal tip portion **2035***a* of the a new surgical staple cartridge **2034***a* is inserted into a corresponding support cavity **5512** in the new cartridge support section **5510** such that the proximal end portion **2037***a* of the new surgical staple cartridge **2034***a* is located in a convenient orientation for enabling the arm cart **1100** to manipulate the surgical end effector **2012** into a position wherein the new cartridge **2034***a* may be automatically loaded into the channel **2022** of the surgical end effector **2012**. In various embodiments, the base **5502** includes at least one sensor **5504** which communicates with the control system **1003** of the robotic controller **1001** to provide the control system **1003** with the location of the base **5502** and/or the reload length and color doe each staged or new cartridge **2034***a*.

As can also be seen in the Figures, the base **5502** further includes a collection receptacle **5520** that is configured to collect spent cartridges **2034***b* that have been removed or disengaged from the surgical end effector **2012** that is operably attached to the robotic system **1000**. In addition, in one form, the automated reloading system **5500** includes an extraction system **5530** for automatically removing the spent end effector component from the corresponding support portion of the end effector or manipulatable surgical tool portion without specific human intervention beyond that which may be necessary to activate the robotic system. In various embodiments, the extraction system **5530** includes an extraction hook member **5532**. In one form, for example, the extraction hook member **5532** is rigidly supported on the base portion **5502**. In one embodiment, the extraction hook member has at least one hook **5534** formed thereon that is configured to hookingly engage the distal end **2035** of a spent cartridge **2034***b* when it is supported in the elongated channel **2022** of the surgical end effector **2012**. In various forms, the extraction hook member **5532** is conveniently located within a portion of the collection receptacle **5520** such that when the spent end effector component (cartridge **2034***b*) is brought into extractive engagement with the extraction hook member **5532**, the spent end effector component (cartridge **2034***b*) is dislodged from the corresponding component support portion (elongated channel **2022**), and falls into the collection receptacle **5020**. Thus, to use this embodiment, the manipulatable surgical tool portion manipulates the end effector attached thereto to bring the distal end **2035** of the spent cartridge **2034***b* therein into hooking engagement with the hook **5534** and then moves the end effector in such a way to dislodge the spent cartridge **2034***b* from the elongated channel **2022**.

In other arrangements, the extraction hook member **5532** comprises a rotatable wheel configuration that has a pair of diametrically-opposed hooks **5334** protruding therefrom. See FIGS. **125** and **128**. The extraction hook member **5532** is rotatably supported within the collection receptacle **5520** and is coupled to an extraction motor **5540** that is controlled by the controller **1001** of the robotic system. This form of the automated reloading system **5500** may be used as follows. FIG. **127** illustrates the introduction of the surgical end effector **2012** that is operably attached to the manipulatable surgical tool portion **1200**. As can be seen in that Figure, the arm cart **1100** of the robotic system **1000** locates the surgical end effector **2012** in the shown position wherein the hook end **5534** of the extraction member **5532** hookingly engages the distal end **2035** of the spent cartridge **2034***b* in the surgical end effector **2012**. The anvil **2024** of the surgical end effector

2012 is in the open position. After the distal end **2035** of the spent cartridge **2034***b* is engaged with the hook end **5532**, the extraction motor **5540** is actuated to rotate the extraction wheel **5532** to disengage the spent cartridge **2034***b* from the channel **2022**. To assist with the disengagement of the spent cartridge **2034***b* from the channel **2022** (or if the extraction member **5530** is stationary), the robotic system **1000** may move the surgical end effector **2012** in an upward direction (arrow "U" in FIG. **128**). As the spent cartridge **2034***b* is dislodged from the channel **2022**, the spent cartridge **2034***b* falls into the collection receptacle **5520**. Once the spent cartridge **2034***b* has been removed from the surgical end effector **2012**, the robotic system **1000** moves the surgical end effector **2012** to the position shown in FIG. **126**.

In various embodiments, a sensor arrangement **5533** is located adjacent to the extraction member **5532** that is in communication with the controller **1001** of the robotic system **1000**. The sensor arrangement **5533** may comprise a sensor that is configured to sense the presence of the surgical end effector **2012** and, more particularly the tip **2035***b* of the spent surgical staple cartridge **2034***b* thereof as the distal tip portion **2035***b* is brought into engagement with the extraction member **5532**. In some embodiments, the sensor arrangement **5533** may comprise, for example, a light curtain arrangement. However, other forms of proximity sensors may be employed. In such arrangement, when the surgical end effector **2012** with the spent surgical staple cartridge **2034***b* is brought into extractive engagement with the extraction member **5532**, the sensor senses the distal tip **2035***b* of the surgical staple cartridge **2034***b* (e.g., the light curtain is broken). When the extraction member **5532** spins and pops the surgical staple cartridge **2034***b* loose and it falls into the collection receptacle **5520**, the light curtain is again unbroken. Because the surgical end effector **2012** was not moved during this procedure, the robotic controller **1001** is assured that the spent surgical staple cartridge **2034***b* has been removed therefrom. Other sensor arrangements may also be successfully employed to provide the robotic controller **1001** with an indication that the spent surgical staple cartridge **2034***b* has been removed from the surgical end effector **2012**.

As can be seen in FIG. **129**, the surgical end effector **2012** is positioned to grasp a new surgical staple cartridge **2034***a* between the channel **2022** and the anvil **2024**. More specifically, as shown in FIGS. **126** and **129**, each cavity **5512** has a corresponding upstanding pressure pad **5514** associated with it. The surgical end effector **2012** is located such that the pressure pad **5514** is located between the new cartridge **2034***a* and the anvil **2024**. Once in that position, the robotic system **1000** closes the anvil **2024** onto the pressure pad **5514** which serves to push the new cartridge **2034***a* into snapping engagement with the channel **2022** of the surgical end effector **2012**. Once the new cartridge **2034***a* has been snapped into position within the elongated channel **2022**, the robotic system **1000** then withdraws the surgical end effector **2012** from the automated cartridge reloading system **5500** for use in connection with performing another surgical procedure.

FIGS. **130-134** depict another automated reloading system **5600** that may be used to remove a spent disposable loading unit **3612** from a manipulatable surgical tool arrangement **3600** (FIGS. **77-90**) that is operably attached to an arm cart **1100** or other portion of a robotic system **1000** and reload a new disposable loading unit **3612** therein. As can be seen in FIGS. **130** and **131**, one form of the automated reloading system **5600** includes a housing **5610** that has a movable support assembly in the form of a rotary carrousel top plate **5620** supported thereon which cooperates with the housing **5610** to form a hollow enclosed area **5612**. The automated reloading system **5600** is configured to be operably supported within the work envelop of the manipulatable surgical tool portion of a robotic system as was described above. In various embodiments, the rotary carrousel plate **5620** has a plurality of holes **5622** for supporting a plurality of orientation tubes **5660** therein. As can be seen in FIGS. **131** and **132**, the rotary carrousel plate **5620** is affixed to a spindle shaft **5624**. The spindle shaft **5624** is centrally disposed within the enclosed area **5612** and has a spindle gear **5626** attached thereto. The spindle gear **5626** is in meshing engagement with a carrousel drive gear **5628** that is coupled to a carrousel drive motor **5630** that is in operative communication with the robotic controller **1001** of the robotic system **1000**.

Various embodiments of the automated reloading system **5600** may also include a carrousel locking assembly, generally designated as **5640**. In various forms, the carrousel locking assembly **5640** includes a cam disc **5642** that is affixed to the spindle shaft **5624**. The spindle gear **5626** may be attached to the underside of the cam disc **5642** and the cam disc **5642** may be keyed onto the spindle shaft **5624**. In alternative arrangements, the spindle gear **5626** and the cam disc **5642** may be independently non-rotatably affixed to the spindle shaft **5624**. As can be seen in FIGS. **131** and **132**, a plurality of notches **5644** are spaced around the perimeter of the cam disc **5642**. A locking arm **5648** is pivotally mounted within the housing **5610** and is biased into engagement with the perimeter of the cam disc **5642** by a locking spring **5649**. As can be seen in FIG. **130**, the outer perimeter of the cam disc **5642** is rounded to facilitate rotation of the cam disc **5642** relative to the locking arm **5648**. The edges of each notch **5644** are also rounded such that when the cam disc **5642** is rotated, the locking arm **5648** is cammed out of engagement with the notches **5644** by the perimeter of the cam disc **5642**.

Various forms of the automated reloading system **5600** are configured to support a portable/replaceable tray assembly **5650** that is configured to support a plurality of disposable loading units **3612** in individual orientation tubes **5660**. More specifically and with reference to FIGS. **131** and **132**, the replaceable tray assembly **5650** comprises a tray **5652** that has a centrally-disposed locator spindle **5654** protruding from the underside thereof. The locator spindle **5654** is sized to be received within a hollow end **5625** of spindle shaft **5624**. The tray **5652** has a plurality of holes **5656** therein that are configured to support an orientation tube **5660** therein. Each orientation tube **5660** is oriented within a corresponding hole **5656** in the replaceable tray assembly **5650** in a desired orientation by a locating fin **5666** on the orientation tube **5660** that is designed to be received within a corresponding locating slot **5658** in the tray assembly **5650**. In at least one embodiment, the locating fin **5666** has a substantially V-shaped cross-sectional shape that is sized to fit within a V-shaped locating slot **5658**. Such arrangement serves to orient the orientation tube **5660** in a desired starting position while enabling it to rotate within the hole **5656** when a rotary motion is applied thereto. That is, when a rotary motion is applied to the orientation tube **5660** the V-shaped locating fin **5666** will pop out of its corresponding locating slot enabling the tube **5660** to rotate relative to the tray **5652** as will be discussed in further detail below. As can also be seen in FIGS. **130-132**, the replaceable tray **5652** may be provided with one or more handle portions **5653** to facilitate transport of the tray assembly **5652** when loaded with orientation tubes **5660**.

As can be seen in FIG. **134**, each orientation tube **5660** comprises a body portion **5662** that has a flanged open end **5664**. The body portion **5662** defines a cavity **5668** that is sized to receive a portion of a disposable loading unit **3612** therein. To properly orient the disposable loading unit **3612** within the orientation tube **5660**, the cavity **5668** has a flat locating surface **5670** formed therein. As can be seen in FIG. **134**, the flat locating surface **5670** is configured to facilitate the insertion of the disposable loading unit into the cavity **5668** in a desired or predetermined non-rotatable orientation. In addition, the end **5669** of the cavity **5668** may include a foam or cushion material **5672** that is designed to cushion the distal end of the disposable loading unit **3612** within the cavity **5668**. Also, the length of the locating surface may cooperate with a sliding support member **3689** of the axial drive assembly **3680** of the disposable loading unit **3612** to further locate the disposable loading unit **3612** at a desired position within the orientation tube **5660**.

The orientation tubes **5660** may be fabricated from Nylon, polycarbonate, polyethylene, liquid crystal polymer, **6061** or **7075** aluminum, titanium, **300** or **400** series stainless steel, coated or painted steel, plated steel, etc. and, when loaded in the replaceable tray **5662** and the locator spindle **5654** is inserted into the hollow end **5625** of spindle shaft **5624**, the orientation tubes **5660** extend through corresponding holes **5662** in the carrousel top plate **5620**. Each replaceable tray **5662** is equipped with a location sensor **5663** that communicates with the control system **1003** of the controller **1001** of the robotic system **1000**. The sensor **5663** serves to identify the location of the reload system, and the number, length, color and fired status of each reload housed in the tray. In addition, an optical sensor or sensors **5665** that communicate with the robotic controller **1001** may be employed to sense the type/size/length of disposable loading units that are loaded within the tray **5662**.

Various embodiments of the automated reloading system **5600** further include a drive assembly **5680** for applying a rotary motion to the orientation tube **5660** holding the disposable loading unit **3612** to be attached to the shaft **3700** of the surgical tool **3600** (collectively the "manipulatable surgical tool portion") that is operably coupled to the robotic system. The drive assembly **5680** includes a support yoke **5682** that is attached to the locking arm **5648**. Thus, the support yoke **5682** pivots with the locking arm **5648**. The support yoke **5682** rotatably supports a tube idler wheel **5684** and a tube drive wheel **5686** that is driven by a tube motor **5688** attached thereto. Tube motor **5688** communicates with the control system **1003** and is controlled thereby. The tube idler wheel **5684** and tube drive wheel **5686** are fabricated from, for example, natural rubber, sanoprene, isoplast, etc. such that the outer surfaces thereof create sufficient amount of friction to result in the rotation of an orientation tube **5660** in contact therewith upon activation of the tube motor **5688**. The idler wheel **5684** and tube drive wheel **5686** are oriented relative to each other to create a cradle area **5687** therebetween for receiving an orientation tube **5060** in driving engagement therein.

In use, one or more of the orientation tubes **5660** loaded in the automated reloading system **5600** are left empty, while the other orientation tubes **5660** may operably support a corresponding new disposable loading unit **3612** therein. As will be discussed in further detail below, the empty orientation tubes **5660** are employed to receive a spent disposable loading unit **3612** therein.

The automated reloading system **5600** may be employed as follows after the system **5600** is located within the work envelope of the manipulatable surgical tool portion of a robotic system. If the manipulatable surgical tool portion has a spent disposable loading unit **3612** operably coupled thereto, one of the orientation tubes **5660** that are supported on the replaceable tray **5662** is left empty to receive the spent disposable loading unit **3612** therein. If, however, the manipulatable surgical tool portion does not have a disposable loading unit **3612** operably coupled thereto, each of the orientation tubes **5660** may be provided with a properly oriented new disposable loading unit **3612**.

As described hereinabove, the disposable loading unit **3612** employs a rotary "bayonet-type" coupling arrangement for operably coupling the disposable loading unit **3612** to a corresponding portion of the manipulatable surgical tool portion. That is, to attach a disposable loading unit **3612** to the corresponding portion of the manipulatable surgical tool portion (**3700**—see FIG. **83**, **84**), a rotary installation motion must be applied to the disposable loading unit **3612** and/or the corresponding portion of the manipulatable surgical tool portion when those components have been moved into loading engagement with each other. Such installation motions are collectively referred to herein as "loading motions". Likewise, to decouple a spent disposable loading unit **3612** from the corresponding portion of the manipulatable surgical tool, a rotary decoupling motion must be applied to the spent disposable loading unit **3612** and/or the corresponding portion of the manipulatable surgical tool portion while simultaneously moving the spent disposable loading unit and the corresponding portion of the manipulatable surgical tool away from each other. Such decoupling motions are collectively referred to herein as "extraction motions".

To commence the loading process, the robotic system **1000** is activated to manipulate the manipulatable surgical tool portion and/or the automated reloading system **5600** to bring the manipulatable surgical tool portion into loading engagement with the new disposable loading unit **3612** that is supported in the orientation tube **5660** that is in driving engagement with the drive assembly **5680**. Once the robotic controller **1001** (FIG. **25**) of the robotic control system **1000** has located the manipulatable surgical tool portion in loading engagement with the new disposable loading unit **3612**, the robotic controller **1001** activates the drive assembly **5680** to apply a rotary loading motion to the orientation tube **5660** in which the new disposable loading unit **3612** is supported and/or applies another rotary loading motion to the corresponding portion of the manipulatable surgical tool portion. Upon application of such rotary loading motions(s), the robotic controller **1001** also causes the corresponding portion of the manipulatable surgical tool portion to be moved towards the new disposable loading unit **3612** into loading engagement therewith. Once the disposable loading unit **3612** is in loading engagement with the corresponding portion of the manipulatable tool portion, the loading motions are discontinued and the manipulatable surgical tool portion may be moved away from the automated reloading system **5600** carrying with it the new disposable loading unit **3612** that has been operably coupled thereto.

To decouple a spent disposable loading unit **3612** from a corresponding manipulatable surgical tool portion, the robotic controller **1001** of the robotic system manipulates the manipulatable surgical tool portion so as to insert the distal end of the spent disposable loading unit **3612** into the empty orientation tube **5660** that remains in driving engagement with the drive assembly **5680**. Thereafter, the robotic controller **1001** activates the drive assembly **5680** to apply a rotary extraction motion to the orientation tube **5660** in which the spent disposable loading unit **3612** is supported and/or applies a rotary extraction motion to the corresponding portion of the manipulatable surgical tool portion. The robotic controller **1001** also causes the manipulatable surgical tool portion to withdraw away from the spent rotary disposable loading unit **3612**. Thereafter the rotary extraction motion(s) are discontinued.

After the spent disposable loading unit **3612** has been removed from the manipulatable surgical tool portion, the robotic controller **1001** may activate the carrousel drive motor **5630** to index the carrousel top plate **5620** to bring another orientation tube **5660** that supports a new disposable loading unit **3612** therein into driving engagement with the drive assembly **5680**. Thereafter, the loading process may be repeated to attach the new disposable loading unit **3612** therein to the portion of the manipulatable surgical tool portion. The robotic controller **1001** may record the number of disposable loading units that have been used from a particular replaceable tray **5652**. Once the controller **1001** determines that all of the new disposable loading units **3612** have been used from that tray, the controller **1001** may provide the surgeon with a signal (visual and/or audible) indicating that the tray **5652** supporting all of the spent disposable loading units **3612** must be replaced with a new tray **5652** containing new disposable loading units **3612**.

FIGS. **135-140** depict another non-limiting embodiment of a surgical tool **6000** of the present invention that is well-adapted for use with a robotic system **1000** that has a tool drive assembly **1010** (FIG. **27**) that is operatively coupled to a master controller **1001** that is operable by inputs from an operator (i.e., a surgeon). As can be seen in FIG. **135**, the surgical tool **6000** includes a surgical end effector **6012** that comprises an endocutter. In at least one form, the surgical tool **6000** generally includes an elongated shaft assembly **6008** that has a proximal closure tube **6040** and a distal closure tube **6042** that are coupled together by an articulation joint **6100**. The surgical tool **6000** is operably coupled to the manipulator by a tool mounting portion, generally designated as **6200**. The surgical tool **6000** further includes an interface **6030** which may mechanically and electrically couple the tool mounting portion **6200** to the manipulator in the various manners described in detail above.

In at least one embodiment, the surgical tool **6000** includes a surgical end effector **6012** that comprises, among other things, at least one component **6024** that is selectively movable between first and second positions relative to at least one other component **6022** in response to various control motions applied to component **6024** as will be discussed in further detail below to perform a surgical procedure. In various embodiments, component **6022** comprises an elongated channel **6022** configured to operably support a surgical staple cartridge **6034** therein and component **6024** comprises a pivotally translatable clamping member, such as an anvil **6024**. Various embodiments of the surgical end effector **6012** are configured to maintain the anvil **6024** and elongated channel **6022** at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector **6012**. Unless otherwise stated, the end effector **6012** is similar to the surgical end effector **2012** described above and includes a cutting instrument (not shown) and a sled (not shown). The anvil **6024** may include a tab **6027** at its proximal end that interacts with a component of the mechanical closure system (described further below) to facilitate the opening of the anvil **6024**. The elongated channel **6022** and the anvil **6024** may be made of an electrically conductive material (such as metal) so that they may serve as part of an antenna that communicates with sensor(s) in the end effector, as described above. The surgical staple cartridge **6034** could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge **6034**, as was also described above.

As can be seen in FIG. **135**, the surgical end effector **6012** is attached to the tool mounting portion **6200** by the elongated shaft assembly **6008** according to various embodiments. As shown in the illustrated embodiment, the elongated shaft assembly **6008** includes an articulation joint generally designated as **6100** that enables the surgical end effector **6012** to be selectively articulated about a first tool articulation axis AA**1**-AA**1** that is substantially transverse to a longitudinal tool axis LT-LT and a second tool articulation axis AA**2**-AA**2** that is substantially transverse to the longitudinal tool axis LT-LT as well as the first articulation axis AA**1**-AA**1**. See FIG. **136**. In various embodiments, the elongated shaft assembly **6008** includes a closure tube assembly **6009** that comprises a proximal closure tube **6040** and a distal closure tube **6042** that are pivotably linked by a pivot links **6044** and **6046**. The closure tube assembly **6009** is movably supported on a spine assembly generally designated as **6102**.

As can be seen in FIG. **137**, the proximal closure tube **6040** is pivotally linked to an intermediate closure tube joint **6043** by an upper pivot link **6044**U and a lower pivot link **6044**L such that the intermediate closure tube joint **6043** is pivotable relative to the proximal closure tube **6040** about a first closure axis CA**1**-CA**1** and a second closure axis CA**2**-CA**2**. In various embodiments, the first closure axis CA**1**-CA**1** is substantially parallel to the second closure axis CA**2**-CA**2** and both closure axes CA**1**-CA**1**, CA**2**-CA**2** are substantially transverse to the longitudinal tool axis LT-LT. As can be further seen in FIG. **134**, the intermediate closure tube joint **6043** is pivotally linked to the distal closure tube **6042** by a left pivot link **6046**L and a right pivot link **6046**R such that the intermediate closure tube joint **6043** is pivotable relative to the distal closure tube **6042** about a third closure axis CA**3**-CA**3** and a fourth closure axis CA**4**-CA**4**. In various embodiments, the third closure axis CA**3**-CA**3** is substantially parallel to the fourth closure axis CA**4**-CA**4** and both closure axes CA**3**-CA**3**, CA**4**-CA**4** are substantially transverse to the first and second closure axes CA**1**-CA**1**, CA**2**-CA**2** as well as to longitudinal tool axis LT-LT.

The closure tube assembly **6009** is configured to axially slide on the spine assembly **6102** in response to actuation motions applied thereto. The distal closure tube **6042** includes an opening **6045** which interfaces with the tab **6027** on the anvil **6024** to facilitate opening of the anvil **6024** as the distal closure tube **6042** is moved axially in the proximal direction "PD". The closure tubes **6040**, **6042** may be made of electrically conductive material (such as metal) so that they may serve as part of the antenna, as described above. Components of the spine assembly **6102** may be made of a nonconductive material (such as plastic).

As indicated above, the surgical tool **6000** includes a tool mounting portion **6200** that is configured for operable attachment to the tool mounting assembly **1010** of the robotic system **1000** in the various manners described in detail above. As can be seen in FIG. **139**, the tool mounting portion **6200** comprises a tool mounting plate **6202** that operably supports a transmission arrangement **6204** thereon. In various embodiments, the transmission arrangement **6204** includes an articulation transmission **6142** that comprises a portion of an articulation system **6140** for articulating the surgical end effector **6012** about a first tool articulation axis TA**1**-TA**1** and a second tool articulation axis TA**2**-TA**2**. The first tool articulation axis TA**1**-TA**1** is substantially transverse to the second tool articulation axis TA**2**-TA**2** and both of the first and second tool articulation axes are substantially transverse to the longitudinal tool axis LT-LT. See FIG. **136**.

To facilitate selective articulation of the surgical end effector **6012** about the first and second tool articulation axes TA**1**-TA**1**, TA**2**-TA**2**, the spine assembly **6102** comprises a proximal spine portion **6110** that is pivotally coupled to a distal spine portion **6120** by pivot pins **6122** for selective pivotal travel about TA1-TA1. Similarly, the distal spine portion **6120** is pivotally attached to the elongated channel **6022** of the surgical end effector **6012** by pivot pins **6124** to enable the surgical end effector **6012** to selectively pivot about the second tool axis TA2-TA2 relative to the distal spine portion **6120**.

In various embodiments, the articulation system **6140** further includes a plurality of articulation elements that operably interface with the surgical end effector **6012** and an articulation control arrangement **6160** that is operably supported in the tool mounting member **6200** as will described in further detail below. In at least one embodiment, the articulation elements comprise a first pair of first articulation cables **6144** and **6146**. The first articulation cables are located on a first or right side of the longitudinal tool axis. Thus, the first articulation cables are referred to herein as a right upper cable **6144** and a right lower cable **6146**. The right upper cable **6144** and the right lower cable **6146** extend through corresponding passages **6147**, **6148**, respectively along the right side of the proximal spine portion **6110**. See FIG. **140**. The articulation system **6140** further includes a second pair of second articulation cables **6150**, **6152**. The second articulation cables are located on a second or left side of the longitudinal tool axis. Thus, the second articulation cables are referred to herein as a left upper articulation cable **6150** and a left articulation cable **6152**. The left upper articulation cable **6150** and the left lower articulation cable **6152** extend through passages **6153**, **6154**, respectively in the proximal spine portion **6110**.

As can be seen in FIG. **136**, the right upper cable **6144** extends around an upper pivot joint **6123** and is attached to a left upper side of the elongated channel **6022** at a left pivot joint **6125**. The right lower cable **6146** extends around a lower pivot joint **6126** and is attached to a left lower side of the elongated channel **6022** at left pivot joint **6125**. The left upper cable **6150** extends around the upper pivot joint **6123** and is attached to a right upper side of the elongated channel **6022** at a right pivot joint **6127**. The left lower cable **6152** extends around the lower pivot joint **6126** and is attached to a right lower side of the elongated channel **6022** at right pivot joint **6127**. Thus, to pivot the surgical end effector **6012** about the first tool articulation axis TA1-TA1 to the left (arrow "L"), the right upper cable **6144** and the right lower cable **6146** must be pulled in the proximal direction "PD". To articulate the surgical end effector **6012** to the right (arrow "R") about the first tool articulation axis TA1-TA1, the left upper cable **6150** and the left lower cable **6152** must be pulled in the proximal direction "PD". To articulate the surgical end effector **6012** about the second tool articulation axis TA2-TA2, in an upward direction (arrow "U"), the right upper cable **6144** and the left upper cable **6150** must be pulled in the proximal direction "PD". To articulate the surgical end effector **6012** in the downward direction (arrow "DW") about the second tool articulation axis TA2-TA2, the right lower cable **6146** and the left lower cable **6152** must be pulled in the proximal direction "PD".

The proximal ends of the articulation cables **6144**, **6146**, **6150**, **6152** are coupled to the articulation control arrangement **6160** which comprises a ball joint assembly that is a part of the articulation transmission **6142**. More specifically and with reference to FIG. **140**, the ball joint assembly **6160** includes a ball-shaped member **6162** that is formed on a proximal portion of the proximal spine **6110**. Movably supported on the ball-shaped member **6162** is an articulation control ring **6164**. As can be further seen in FIG. **140**, the proximal ends of the articulation cables **6144**, **6146**, **6150**, **6152** are coupled to the articulation control ring **6164** by corresponding ball joint arrangements **6166**. The articulation control ring **6164** is controlled by an articulation drive assembly **6170**. As can be most particularly seen in FIG. **140**, the proximal ends of the first articulation cables **6144**, **6146** are attached to the articulation control ring **6164** at corresponding spaced first points **6149**, **6151** that are located on plane **6159**. Likewise, the proximal ends of the second articulation cables **6150**, **6152** are attached to the articulation control ring **6164** at corresponding spaced second points **6153**, **6155** that are also located along plane **6159**. As the present Detailed Description proceeds, those of ordinary skill in the art will appreciate that such cable attachment configuration on the articulation control ring **6164** facilitates the desired range of articulation motions as the articulation control ring **6164** is manipulated by the articulation drive assembly **6170**.

In various forms, the articulation drive assembly **6170** comprises a horizontal articulation assembly generally designated as **6171**. In at least one form, the horizontal articulation assembly **6171** comprises a horizontal push cable **6172** that is attached to a horizontal gear arrangement **6180**. The articulation drive assembly **6170** further comprises a vertically articulation assembly generally designated as **6173**. In at least one form, the vertical articulation assembly **6173** comprises a vertical push cable **6174** that is attached to a vertical gear arrangement **6190**. As can be seen in FIGS. **139** and **140**, the horizontal push cable **6172** extends through a support plate **6167** that is attached to the proximal spine portion **6110**. The distal end of the horizontal push cable **6174** is attached to the articulation control ring **6164** by a corresponding ball/pivot joint **6168**. The vertical push cable **6174** extends through the support plate **6167** and the distal end thereof is attached to the articulation control ring **6164** by a corresponding ball/pivot joint **6169**.

The horizontal gear arrangement **6180** includes a horizontal driven gear **6182** that is pivotally mounted on a horizontal shaft **6181** that is attached to a proximal portion of the proximal spine portion **6110**. The proximal end of the horizontal push cable **6172** is pivotally attached to the horizontal driven gear **6182** such that, as the horizontal driven gear **6172** is rotated about horizontal pivot axis HA, the horizontal push cable **6172** applies a first pivot motion to the articulation control ring **6164**. Likewise, the vertical gear arrangement **6190** includes a vertical driven gear **6192** that is pivotally supported on a vertical shaft **6191** attached to the proximal portion of the proximal spine portion **6110** for pivotal travel about a vertical pivot axis VA. The proximal end of the vertical push cable **6174** is pivotally attached to the vertical driven gear **6192** such that as the vertical driven gear **6192** is rotated about vertical pivot axis VA, the vertical push cable **6174** applies a second pivot motion to the articulation control ring **6164**.

The horizontal driven gear **6182** and the vertical driven gear **6192** are driven by an articulation gear train **6300** that operably interfaces with an articulation shifter assembly **6320**. In at least one form, the articulation shifter assembly comprises an articulation drive gear **6322** that is coupled to a corresponding one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **6202**. See FIG. **34**. Thus, application of a rotary input motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding driven element **1304** will cause rotation of the articulation drive gear **6322** when the interface **1230** is coupled to the tool holder **1270**. An articulation driven gear **6324** is attached to a splined shifter shaft **6330** that is rotatably supported on the tool mounting plate **6202**. The articulation driven gear **6324** is in meshing engagement with the articulation drive gear **6322** as shown. Thus, rotation of the articulation drive gear **6322** will result in the rotation of the shaft

6330. In various forms, a shifter driven gear assembly **6340** is movably supported on the splined portion **6332** of the shifter shaft **6330**.

In various embodiments, the shifter driven gear assembly **6340** includes a driven shifter gear **6342** that is attached to a shifter plate **6344**. The shifter plate **6344** operably interfaces with a shifter solenoid assembly **6350**. The shifter solenoid assembly **6350** is coupled to corresponding pins **6352** by conductors **6352**. See FIG. **139**. Pins **6352** are oriented to electrically communicate with slots **1258** (FIG. **33**) on the tool side **1244** of the adaptor **1240**. Such arrangement serves to electrically couple the shifter solenoid assembly **6350** to the robotic controller **1001**. Thus, activation of the shifter solenoid **6350** will shift the shifter driven gear assembly **6340** on the splined portion **6332** of the shifter shaft **6330** as represented by arrow "S" in FIGS. **139** and **140**. Various embodiments of the articulation gear train **6300** further include a horizontal gear assembly **6360** that includes a first horizontal drive gear **6362** that is mounted on a shaft **6361** that is rotatably attached to the tool mounting plate **6202**. The first horizontal drive gear **6362** is supported in meshing engagement with a second horizontal drive gear **6364**. As can be seen in FIG. **140**, the horizontal driven gear **6182** is in meshing engagement with the distal face portion **6365** of the second horizontal driven gear **6364**.

Various embodiments of the articulation gear train **6300** further include a vertical gear assembly **6370** that includes a first vertical drive gear **6372** that is mounted on a shaft **6371** that is rotatably supported on the tool mounting plate **6202**. The first vertical drive gear **6372** is supported in meshing engagement with a second vertical drive gear **6374** that is concentrically supported with the second horizontal drive gear **6364**. The second vertical drive gear **6374** is rotatably supported on the proximal spine portion **6110** for travel therearound. The second horizontal drive gear **6364** is rotatably supported on a portion of said second vertical drive gear **6374** for independent rotatable travel thereon. As can be seen in FIG. **140**, the vertical driven gear **6192** is in meshing engagement with the distal face portion **6375** of the second vertical driven gear **6374**.

In various forms, the first horizontal drive gear **6362** has a first diameter and the first vertical drive gear **6372** has a second diameter. As can be seen in FIGS. **139** and **140**, the shaft **6361** is not on a common axis with shaft **6371**. That is, the first horizontal driven gear **6362** and the first vertical driven gear **6372** do not rotate about a common axis. Thus, when the shifter gear **6342** is positioned in a center "locking" position such that the shifter gear **6342** is in meshing engagement with both the first horizontal driven gear **6362** and the first vertical drive gear **6372**, the components of the articulation system **6140** are locked in position. Thus, the shiftable shifter gear **6342** and the arrangement of first horizontal and vertical drive gears **6362**, **6372** as well as the articulation shifter assembly **6320** collectively may be referred to as an articulation locking system, generally designated as **6380**.

In use, the robotic controller **1001** of the robotic system **1000** may control the articulation system **6140** as follows. To articulate the end effector **6012** to the left about the first tool articulation axis TA**1**-TA**1**, the robotic controller **1001** activates the shifter solenoid assembly **6350** to bring the shifter gear **6342** into meshing engagement with the first horizontal drive gear **6362**. Thereafter, the controller **1001** causes a first rotary output motion to be applied to the articulation drive gear **6322** to drive the shifter gear in a first direction to ultimately drive the horizontal driven gear **6182** in another first direction. The horizontal driven gear **6182** is driven to pivot the articulation ring **6164** on the ball-shaped portion **6162** to thereby pull right upper cable **6144** and the right lower cable **6146** in the proximal direction "PD". To articulate the end effector **6012** to the right about the first tool articulation axis TA**1**-TA**1**, the robotic controller **1001** activates the shifter solenoid assembly **6350** to bring the shifter gear **6342** into meshing engagement with the first horizontal drive gear **6362**. Thereafter, the controller **1001** causes the first rotary output motion in an opposite direction to be applied to the articulation drive gear **6322** to drive the shifter gear **6342** in a second direction to ultimately drive the horizontal driven gear **6182** in another second direction. Such actions result in the articulation control ring **6164** moving in such a manner as to pull the left upper cable **6150** and the left lower cable **6152** in the proximal direction "PD". In various embodiments the gear ratios and frictional forces generated between the gears of the vertical gear assembly **6370** serve to prevent rotation of the vertical driven gear **6192** as the horizontal gear assembly **6360** is actuated.

To articulate the end effector **6012** in the upper direction about the second tool articulation axis TA**2**-TA**2**, the robotic controller **1001** activates the shifter solenoid assembly **6350** to bring the shifter gear **6342** into meshing engagement with the first vertical drive gear **6372**. Thereafter, the controller **1001** causes the first rotary output motion to be applied to the articulation drive gear **6322** to drive the shifter gear **6342** in a first direction to ultimately drive the vertical driven gear **6192** in another first direction. The vertical driven gear **6192** is driven to pivot the articulation ring **6164** on the ball-shaped portion **6162** of the proximal spine portion **6110** to thereby pull right upper cable **6144** and the left upper cable **6150** in the proximal direction "PD". To articulate the end effector **6012** in the downward direction about the second tool articulation axis TA**2**-TA**2**, the robotic controller **1001** activates the shifter solenoid assembly **6350** to bring the shifter gear **6342** into meshing engagement with the first vertical drive gear **6372**. Thereafter, the controller **1001** causes the first rotary output motion to be applied in an opposite direction to the articulation drive gear **6322** to drive the shifter gear **6342** in a second direction to ultimately drive the vertical driven gear **6192** in another second direction. Such actions thereby cause the articulation control ring **6164** to pull the right lower cable **6146** and the left lower cable **6152** in the proximal direction "PD". In various embodiments, the gear ratios and frictional forces generated between the gears of the horizontal gear assembly **6360** serve to prevent rotation of the horizontal driven gear **6182** as the vertical gear assembly **6370** is actuated.

In various embodiments, a variety of sensors may communicate with the robotic controller **1001** to determine the articulated position of the end effector **6012**. Such sensors may interface with, for example, the articulation joint **6100** or be located within the tool mounting portion **6200**. For example, sensors may be employed to detect the position of the articulation control ring **6164** on the ball-shaped portion **6162** of the proximal spine portion **6110**. Such feedback from the sensors to the controller **1001** permits the controller **1001** to adjust the amount of rotation and the direction of the rotary output to the articulation drive gear **6322**. Further, as indicated above, when the shifter drive gear **6342** is centrally positioned in meshing engagement with the first horizontal drive gear **6362** and the first vertical drive gear **6372**, the end effector **6012** is locked in the articulated position. Thus, after the desired amount of articulation has been attained, the controller **1001** may activate the shifter solenoid assembly **6350** to bring the shifter gear **6342** into meshing engagement with the first horizontal drive gear **6362** and the first vertical drive gear **6372**. In alternative embodiments, the shifter solenoid assembly **6350** may be spring activated to the central locked position.

In use, it may be desirable to rotate the surgical end effector **6012** about the longitudinal tool axis LT-LT. In at least one embodiment, the transmission arrangement **6204** on the tool mounting portion includes a rotational transmission assembly **6400** that is configured to receive a corresponding rotary output motion from the tool drive assembly **1010** of the robotic system **1000** and convert that rotary output motion to a rotary control motion for rotating the elongated shaft assembly **6008** (and surgical end effector **6012**) about the longitudinal tool axis LT-LT. In various embodiments, for example, a proximal end portion **6041** of the proximal closure tube **6040** is rotatably supported on the tool mounting plate **6202** of the tool mounting portion **6200** by a forward support cradle **6205** and a closure sled **6510** that is also movably supported on the tool mounting plate **6202**. In at least one form, the rotational transmission assembly **6400** includes a tube gear segment **6402** that is formed on (or attached to) the proximal end **6041** of the proximal closure tube **6040** for operable engagement by a rotational gear assembly **6410** that is operably supported on the tool mounting plate **6202**. As can be seen in FIG. **139**, the rotational gear assembly **6410**, in at least one embodiment, comprises a rotation drive gear **6412** that is coupled to a corresponding second one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **6202** when the tool mounting portion **6200** is coupled to the tool drive assembly **1010**. See FIG. **34**. The rotational gear assembly **6410** further comprises a first rotary driven gear **6414** that is rotatably supported on the tool mounting plate **6202** in meshing engagement with the rotation drive gear **6412**. The first rotary driven gear **6414** is attached to a drive shaft **6416** that is rotatably supported on the tool mounting plate **6202**. A second rotary driven gear **6418** is attached to the drive shaft **6416** and is in meshing engagement with tube gear segment **6402** on the proximal closure tube **6040**. Application of a second rotary output motion from the tool drive assembly **1010** of the robotic system **1000** to the corresponding driven element **1304** will thereby cause rotation of the rotation drive gear **6412**. Rotation of the rotation drive gear **6412** ultimately results in the rotation of the elongated shaft assembly **6008** (and the surgical end effector **6012**) about the longitudinal tool axis LT-LT. It will be appreciated that the application of a rotary output motion from the tool drive assembly **1010** in one direction will result in the rotation of the elongated shaft assembly **6008** and surgical end effector **6012** about the longitudinal tool axis LT-LT in a first direction and an application of the rotary output motion in an opposite direction will result in the rotation of the elongated shaft assembly **6008** and surgical end effector **6012** in a second direction that is opposite to the first direction.

In at least one embodiment, the closure of the anvil **2024** relative to the staple cartridge **2034** is accomplished by axially moving a closure portion of the elongated shaft assembly **2008** in the distal direction "DD" on the spine assembly **2049**. As indicated above, in various embodiments, the proximal end portion **6041** of the proximal closure tube **6040** is supported by the closure sled **6510** which comprises a portion of a closure transmission, generally depicted as **6512**. As can be seen in FIG. **139**, the proximal end portion **6041** of the proximal closure tube portion **6040** has a collar **6048** formed thereon. The closure sled **6510** is coupled to the collar **6048** by a yoke **6514** that engages an annular groove **6049** in the collar **6048**. Such arrangement serves to enable the collar **6048** to rotate about the longitudinal tool axis LT-LT while still being coupled to the closure transmission **6512**. In various embodiments, the closure sled **6510** has an upstanding portion **6516** that has a closure rack gear **6518** formed thereon. The closure rack gear **6518** is configured for driving engagement with a closure gear assembly **6520**. See FIG. **139**.

In various forms, the closure gear assembly **6520** includes a closure spur gear **6522** that is coupled to a corresponding second one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **6202**. See FIG. **34**. Thus, application of a third rotary output motion from the tool drive assembly **1010** of the robotic system **1000** to the corresponding second driven element **1304** will cause rotation of the closure spur gear **6522** when the tool mounting portion **6202** is coupled to the tool drive assembly **1010**. The closure gear assembly **6520** further includes a closure reduction gear set **6524** that is supported in meshing engagement with the closure spur gear **6522** and the closure rack gear **2106**. Thus, application of a third rotary output motion from the tool drive assembly **1010** of the robotic system **1000** to the corresponding second driven element **1304** will cause rotation of the closure spur gear **6522** and the closure transmission **6512** and ultimately drive the closure sled **6510** and the proximal closure tube **6040** axially on the proximal spine portion **6110**. The axial direction in which the proximal closure tube **6040** moves ultimately depends upon the direction in which the third driven element **1304** is rotated. For example, in response to one rotary output motion received from the tool drive assembly **1010** of the robotic system **1000**, the closure sled **6510** will be driven in the distal direction "DD" and ultimately drive the proximal closure tube **6040** in the distal direction "DD". As the proximal closure tube **6040** is driven distally, the distal closure tube **6042** is also driven distally by virtue of it connection with the proximal closure tube **6040**. As the distal closure tube **6042** is driven distally, the end of the closure tube **6042** will engage a portion of the anvil **6024** and cause the anvil **6024** to pivot to a closed position. Upon application of an "opening" out put motion from the tool drive assembly **1010** of the robotic system **1000**, the closure sled **6510** and the proximal closure tube **6040** will be driven in the proximal direction "PD" on the proximal spine portion **6110**. As the proximal closure tube **6040** is driven in the proximal direction "PD", the distal closure tube **6042** will also be driven in the proximal direction "PD". As the distal closure tube **6042** is driven in the proximal direction "PD", the opening **6045** therein interacts with the tab **6027** on the anvil **6024** to facilitate the opening thereof. In various embodiments, a spring (not shown) may be employed to bias the anvil **6024** to the open position when the distal closure tube **6042** has been moved to its starting position. In various embodiments, the various gears of the closure gear assembly **6520** are sized to generate the necessary closure forces needed to satisfactorily close the anvil **6024** onto the tissue to be cut and stapled by the surgical end effector **6012**. For example, the gears of the closure transmission **6520** may be sized to generate approximately 70-120 pounds of closure forces.

In various embodiments, the cutting instrument is driven through the surgical end effector **6012** by a knife bar **6530**. See FIG. **139**. In at least one form, the knife bar **6530** is fabricated with a joint arrangement (not shown) and/or is fabricated from material that can accommodate the articulation of the surgical end effector **6102** about the first and second tool articulation axes while remaining sufficiently rigid so as to push the cutting instrument through tissue clamped in the surgical end effector **6012**. The knife bar **6530** extends through a hollow passage **6532** in the proximal spine portion **6110**.

In various embodiments, a proximal end **6534** of the knife bar **6530** is rotatably affixed to a knife rack gear **6540** such that the knife bar **6530** is free to rotate relative to the knife rack gear **6540**. The distal end of the knife bar **6530** is attached to the cutting instrument in the various manners described above. As can be seen in FIG. **139**, the knife rack gear **6540** is slidably supported within a rack housing **6542** that is attached to the tool mounting plate **6202** such that the knife rack gear **6540** is retained in meshing engagement with a knife drive transmission portion **6550** of the transmission arrangement **6204**. In various embodiments, the knife drive transmission portion **6550** comprises a knife gear assembly **6560**. More specifically and with reference to FIG. **139**, in at least one embodiment, the knife gear assembly **6560** includes a knife spur gear **6562** that is coupled to a corresponding fourth one of the driven discs or elements **1304** on the adapter side **1307** of the tool mounting plate **6202**. See FIG. **34**. Thus, application of another rotary output motion from the robotic system **1000** through the tool drive assembly **1010** to the corresponding fourth driven element **1304** will cause rotation of the knife spur gear **6562**. The knife gear assembly **6560** further includes a knife gear reduction set **6564** that includes a first knife driven gear **6566** and a second knife drive gear **6568**. The knife gear reduction set **6564** is rotatably mounted to the tool mounting plate **6202** such that the firs knife driven gear **6566** is in meshing engagement with the knife spur gear **6562**. Likewise, the second knife drive gear **6568** is in meshing engagement with a third knife drive gear assembly **6570**. As shown in FIG. **139**, the second knife driven gear **6568** is in meshing engagement with a fourth knife driven gear **6572** of the third knife drive gear assembly **6570**. The fourth knife driven gear **6572** is in meshing engagement with a fifth knife driven gear assembly **6574** that is in meshing engagement with the knife rack gear **6540**. In various embodiments, the gears of the knife gear assembly **6560** are sized to generate the forces needed to drive the cutting instrument through the tissue clamped in the surgical end effector **6012** and actuate the staples therein. For example, the gears of the knife gear assembly **6560** may be sized to generate approximately 40 to 100 pounds of driving force. It will be appreciated that the application of a rotary output motion from the tool drive assembly **1010** in one direction will result in the axial movement of the cutting instrument in a distal direction and application of the rotary output motion in an opposite direction will result in the axial travel of the cutting instrument in a proximal direction.

As can be appreciated from the foregoing description, the surgical tool **6000** represents a vast improvement over prior robotic tool arrangements. The unique and novel transmission arrangement employed by the surgical tool **6000** enables the tool to be operably coupled to a tool holder portion **1010** of a robotic system that only has four rotary output bodies, yet obtain the rotary output motions therefrom to: (i) articulate the end effector about two different articulation axes that are substantially transverse to each other as well as the longitudinal tool axis; (ii) rotate the end effector **6012** about the longitudinal tool axis; (iii) close the anvil **6024** relative to the surgical staple cartridge **6034** to varying degrees to enable the end effector **6012** to be used to manipulate tissue and then clamp it into position for cutting and stapling; and (iv) firing the cutting instrument to cut through the tissue clamped within the end effector **6012**. The unique and novel shifter arrangements of various embodiments of the present invention described above enable two different articulation actions to be powered from a single rotatable body portion of the robotic system.

The various embodiments of the present invention have been described above in connection with cutting-type surgical instruments. It should be noted, however, that in other embodiments, the inventive surgical instrument disclosed herein need not be a cutting-type surgical instrument, but rather could be used in any type of surgical instrument including remote sensor transponders. For example, it could be a non-cutting endoscopic instrument, a grasper, a stapler, a clip applier, an access device, a drug/gene therapy delivery device, an energy device using ultrasound, RF, laser, etc. In addition, the present invention may be in laparoscopic instruments, for example. The present invention also has application in conventional endoscopic and open surgical instrumentation as well as robotic-assisted surgery.

FIG. **141** depicts use of various aspects of certain embodiments of the present invention in connection with a surgical tool **7000** that has an ultrasonically powered end effector **7012**. The end effector **7012** is operably attached to a tool mounting portion **7100** by an elongated shaft assembly **7008**. The tool mounting portion **7100** may be substantially similar to the various tool mounting portions described hereinabove. In one embodiment, the end effector **7012** includes an ultrasonically powered jaw portion **7014** that is powered by alternating current or direct current in a known manner. Such ultrasonically-powered devices are disclosed, for example, in U.S. Pat. No. 6,783,524, entitled "Robotic Surgical Tool With Ultrasound Cauterizing and Cutting Instrument", the entire disclosure of which is herein incorporated by reference. In the illustrated embodiment, a separate power cord **7020** is shown. It will be understood, however, that the power may be supplied thereto from the robotic controller **1001** through the tool mounting portion **7100**. The surgical end effector **7012** further includes a movable jaw **7016** that may be used to clamp tissue onto the ultrasonic jaw portion **7014**. The movable jaw portion **7016** may be selectively actuated by the robotic controller **1001** through the tool mounting portion **7100** in anyone of the various manners herein described.

FIG. **142** illustrates use of various aspects of certain embodiments of the present invention in connection with a surgical tool **8000** that has an end effector **8012** that comprises a linear stapling device. The end effector **8012** is operably attached to a tool mounting portion **8100** by an elongated shaft assembly **3700** of the type and construction describe above. However, the end effector **8012** may be attached to the tool mounting portion **8100** by a variety of other elongated shaft assemblies described herein. In one embodiment, the tool mounting portion **8100** may be substantially similar to tool mounting portion **3750**. However, various other tool mounting portions and their respective transmission arrangements describe in detail herein may also be employed. Such linear stapling head portions are also disclosed, for example, in U.S. Pat. No. 7,673,781, entitled "Surgical Stapling Device With Staple Driver That Supports Multiple Wire Diameter Staples", the entire disclosure of which is herein incorporated by reference.

Various sensor embodiments described in U.S. Patent Publication No. 2011/0062212 A1 to Shelton, IV et al., the disclosure of which is herein incorporated by reference in its entirety, may be employed with many of the surgical tool embodiments disclosed herein. As was indicated above, the master controller **1001** generally includes master controllers (generally represented by **1003**) which are grasped by the surgeon and manipulated in space while the surgeon views the procedure via a stereo display **1002**. See FIG. **25**. The master controllers **1001** are manual input devices which preferably move with multiple degrees of freedom, and which often further have an actuatable handle for actuating the surgical tools. Some of the surgical tool embodiments disclosed herein employ a motor or motors in their tool drive portion to supply various control motions to the tool's end effector. Such embodiments may also obtain additional control motion(s) from the motor arrangement employed in the robotic system components. Other embodiments disclosed herein obtain all of the control motions from motor arrangements within the robotic system.

Such motor powered arrangements may employ various sensor arrangements that are disclosed in the published US patent application cited above to provide the surgeon with a variety of forms of feedback without departing from the spirit and scope of the present invention. For example, those master controller arrangements **1003** that employ a manually actuatable firing trigger can employ run motor sensor(s) to provide the surgeon with feedback relating to the amount of force applied to or being experienced by the cutting member. The run motor sensor(s) may be configured for communication with the firing trigger portion to detect when the firing trigger portion has been actuated to commence the cutting/stapling operation by the end effector. The run motor sensor may be a proportional sensor such as, for example, a rheostat or variable resistor. When the firing trigger is drawn in, the sensor detects the movement, and sends an electrical signal indicative of the voltage (or power) to be supplied to the corresponding motor. When the sensor is a variable resistor or the like, the rotation of the motor may be generally proportional to the amount of movement of the firing trigger. That is, if the operator only draws or closes the firing trigger in a small amount, the rotation of the motor is relatively low. When the firing trigger is fully drawn in (or in the fully closed position), the rotation of the motor is at its maximum. In other words, the harder the surgeon pulls on the firing trigger, the more voltage is applied to the motor causing greater rates of rotation. Other arrangements may provide the surgeon with a feed back meter **1005** that may be viewed through the display **1002** and provide the surgeon with a visual indication of the amount of force being applied to the cutting instrument or dynamic clamping member. Other sensor arrangements may be employed to provide the master controller **1001** with an indication as to whether a staple cartridge has been loaded into the end effector, whether the anvil has been moved to a closed position prior to firing, etc.

In alternative embodiments, a motor-controlled interface may be employed in connection with the controller **1001** that limit the maximum trigger pull based on the amount of loading (e.g., clamping force, cutting force, etc.) experienced by the surgical end effector. For example, the harder it is to drive the cutting instrument through the tissue clamped within the end effector, the harder it would be to pull/actuate the activation trigger. In still other embodiments, the trigger on the controller **1001** is arranged such that the trigger pull location is proportionate to the end effector-location/condition. For example, the trigger is only fully depressed when the end effector is fully fired.

In still other embodiments, the various robotic systems and tools disclosed herein may employ many of the sensor/transponder arrangements disclosed above. Such sensor arrangements may include, but are not limited to, run motor sensors, reverse motor sensors, stop motor sensors, end-of-stroke sensors, beginning-of-stroke sensors, cartridge lockout sensors, sensor transponders, charge accumulating devices, switching circuits, removable battery packs, etc. The sensors may be employed in connection with any of the surgical tools disclosed herein that are adapted for use with a robotic system. The sensors may be configured to communicate with the robotic system controller. In other embodiments, components of the shaft/end effector may serve as antennas to communicate between the sensors and the robotic controller. In still other embodiments, the various remote programming device arrangements described above may also be employed with the robotic controller.

The devices disclosed herein can be designed to be disposed of after a single use, or they can be designed to be used multiple times. In either case, however, the device can be reconditioned for reuse after at least one use. Reconditioning can include any combination of the steps of disassembly of the device, followed by cleaning or replacement of particular pieces, and subsequent reassembly. In particular, the device can be disassembled, and any number of the particular pieces or parts of the device can be selectively replaced or removed in any combination. Upon cleaning and/or replacement of particular parts, the device can be reassembled for subsequent use either at a reconditioning facility, or by a surgical team immediately prior to a surgical procedure. Those skilled in the art will appreciate that reconditioning of a device can utilize a variety of techniques for disassembly, cleaning/replacement, and reassembly. Use of such techniques, and the resulting reconditioned device, are all within the scope of the present application.

Although the present invention has been described herein in connection with certain disclosed embodiments, many modifications and variations to those embodiments may be implemented. For example, different types of end effectors may be employed. Also, where materials are disclosed for certain components, other materials may be used. The foregoing description and following claims are intended to cover all such modification and variations.

Any patent, publication, or other disclosure material, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated materials does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

What is claimed is:

1. A robotically-controlled surgical instrument system comprising:

an end effector comprising a moveable cutting instrument;

an electric motor communicating with said end effector for actuating the cutting instrument;

a motor control circuit for controlling the motor, wherein the motor control circuit comprises:

a robotic system operably communicating with said electric motor, the robotic system comprising a power supply for supplying power to the electric motor;

a charge accumulator device; and

a switching circuit communicating with the robotic system and the charge accumulator device for (i) temporarily connecting the charge accumulator device to the robotic system not in series with the power supply to charge the charge accumulator device, and (ii) selectively connecting the charge accumulator device in series between the motor and the robotic system to provide additional power to the motor.

2. The surgical instrument system of claim **1**, wherein the charge accumulator device comprises a capacitor.

3. The surgical instrument system of claim **2**, wherein the charge accumulator device comprises an ultracapacitor.

4. The surgical instrument system of claim **1**, wherein the robotic system comprises a plurality of power sources.

5. The surgical instrument of claim **4**, wherein said plurality of power sources comprises series-connected battery cells.

6. The surgical instrument system of claim **4**, further comprising a power source selection switch connected to the robotic system for connecting, when in a first state, all of the power sources to the motor, and, when in a second state, a subset of the power sources to the motor.

7. The surgical instrument system of claim **1**, wherein the end effector comprises a circular-cutting end effector.

8. The surgical instrument system of claim **1**, wherein the end effector comprises a linear-cutting end effector.

9. The surgical instrument system of claim **1**, wherein the motor control circuit further comprises a current control circuit, connected to the power supply, for varying the current supplied to the motor from the power supply, such that the motor has at least:

a first, low power operational mode for a first portion of a cutting stroke cycle of the cutting instrument; and

a second, high power operational mode for a second portion of the cutting stroke cycle of the cutting instrument.

10. The surgical instrument system of claim **1**, wherein:

the motor comprises at least two windings; and the motor control circuit is for selectively connecting the at least two windings in series or in parallel.

11. A surgical instrument system comprising:

a robotic system;

an end effector coupled to a portion of said robotic system, said end effector comprising a moveable cutting instrument;

an electric motor for actuating the cutting instrument, wherein the motor comprises at least two windings; and

a motor control circuit connected to the motor, the motor control circuit having a first configuration where the at least two motor windings are connected in series and a second configuration where the at least two motor windings are connected in parallel.

12. The surgical instrument system of claim **11**, wherein said robotic system comprises a power source connected to the motor.

13. The surgical instrument system of claim **12**, wherein the power source comprises a plurality of series-connected power sources.

14. The surgical instrument system of claim **13**, further comprising a power source selection switch connected to the power sources for connecting, when in a first state, all of the power sources to the motor, and, when in a second state, a subset of the power sources to the motor.

15. A surgical instrument system comprising:

an end effector operably coupled to a robotic system, said end effector comprising

a moveable cutting instrument;

an electric motor for actuating the cutting instrument;

a removable battery pack within said robotic system for powering the motor, wherein the battery pack comprises a plurality of battery cells, wherein the plurality of battery cells comprises a first plurality of series-connected battery cells and a second plurality of series-connected battery cells;

a battery cell connector, separate from the battery pack and in mechanical communication with the battery pack, that connects the battery pack to the surgical instrument system and connects in series the first plurality of series-connected battery cells to the second plurality of series-connected battery cells when the battery pack is connected to the surgical instrument system, wherein the first plurality of series-connected battery cells and the second plurality of series-connected battery cells are not connected in series prior to connection to the surgical instrument system; and

a switch electrically connected to the battery pack, wherein the switch has a first position in which the first plurality of series-connected battery cells and the second plurality of series-connected battery cells are electrically coupled to power the electric motor and a second position in which less than all of the first plurality of series-connected battery cells and the second plurality of series-connected battery cells are electrically coupled to power the electric motor.

16. The surgical instrument system of claim **15**, wherein the battery pack comprises a third plurality of series-connected battery cells, and wherein the battery cell connector connects in series the first, second, and third plurality of series-connected battery cells when the battery pack is in communication with the surgical instrument system.

17. The surgical instrument system of claim **15**, wherein the first plurality of series-connected battery cells comprises three series-connected Lithium primary battery cells and the second plurality of series-connected battery cells comprises three series-connected Lithium primary battery cells.

18. The surgical instrument system of claim **15**, wherein the surgical instrument system further comprises:

a charge accumulator device; and

a switching circuit connected to the battery pack and the charge accumulator device for (i) temporarily connecting the charge accumulator device to the battery pack not in series with the battery pack to charge the charge accumulator device, and (ii) selectively connecting the charge accumulator device in series with the battery pack to provide additional power to the motor.

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